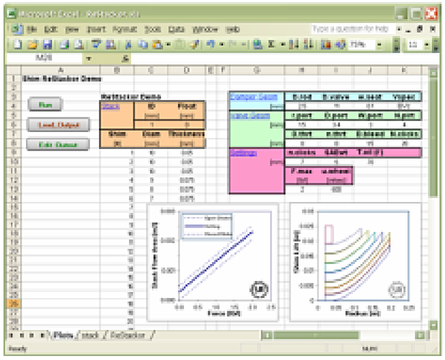
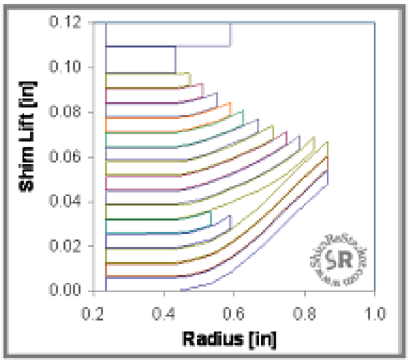
Shim ReStackor User Manual

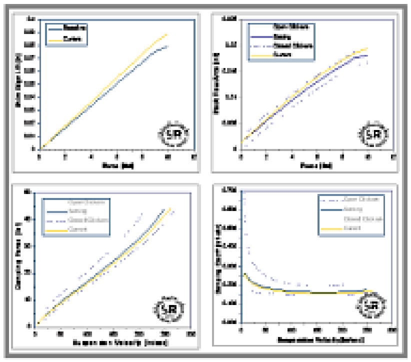
Simple Inputs..



Thorough analysis..

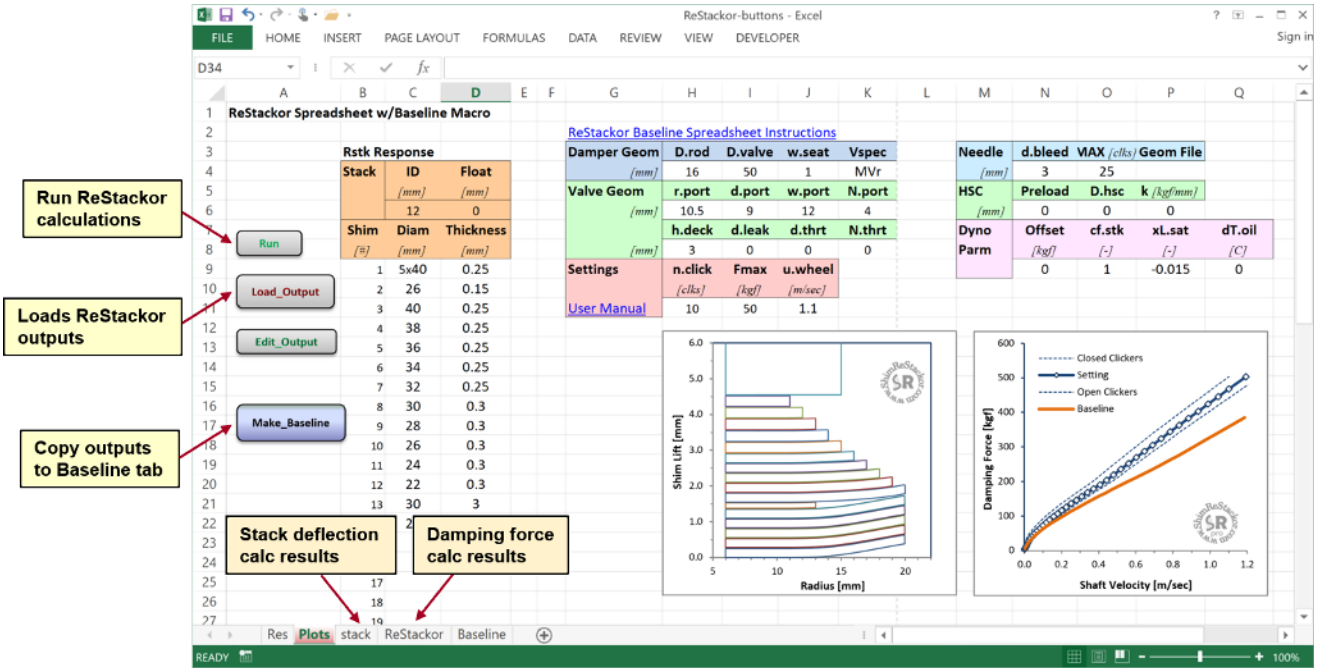


Practical results.



- **Basic:** Single valve and shim stack damping force
    - Spreadsheet operation
    - Inputs and outputs
    - Shim ReStackor code key
- **Mid-valve:** Combined damping force of base and mid-valve with cavitation effects
- **Weight scaling:** Modify damping for a change in spring rate or rider weight
- **Suspension Response:** Compute jump landing bottoming velocity, rebound response and damping targets for a baseline suspension setup

Spreadsheet operation



Run ReStackor calculations

Loads ReStackor outputs

Copy outputs to Baseline tab

Stack deflection calc results

Damping force calc results

ReStackor Spreadsheet w/Baseline Macro

Rstk Response

Stack	ID	Float
	[mm]	*[mm]*
	12	0
Shim	**Diam**	**Thickness**
[#]	*[mm]*	*[mm]*
1	5x40	0.25
2	26	0.15
3	40	0.25
4	38	0.25
5	36	0.25
6	34	0.25
7	32	0.25
8	30	0.3
9	28	0.3
10	26	0.3
11	24	0.3
12	22	0.3
13	30	3
17		
18		
19		

ReStackor Baseline Spreadsheet Instructions

Damper Geom	D.rod	D.valve	w.seat	Vspec
[mm]	16	50	1	MVr
Valve Geom	**r.port**	**d.port**	**w.port**	**N.port**
[mm]	10.5	9	12	4
	h.deck	**d.leak**	**d.thrt**	**N.thrt**
[mm]	3	0	0	0
Settings	**n.click**	**Fmax**	**u.wheel**	
	[clks]	*[kgf]*	*[m/sec]*	
User Manual	10	50	1.1	

Needle	d.bleed	VIAX *[clks]*	Geom File	
[mm]	3	25		
HSC	**Preload**	**D.hsc**	**k** *[kgf/mm]*	
[mm]	0	0	0	
Dyno Parm	**Offset**	**cf.stk**	**xL.sat**	**dT.oil**
	[kgf]	*[-]*	*[-]*	*[C]*
	0	1	-0.015	0

Figure 1: Run button launches ReStackor calculations; Load Output button loads calculation results into spreadsheet

Basic ReStackor spreadsheet

The basic ReStackor.xls spreadsheet runs a single shock absorber valve in a single stroke direction. The spreadsheet is applicable to fork base valves, fork mid-valves, compression adjusters and the shock absorber main piston.

All Shim ReStackor spreadsheets use the same input format to describe the shim stack configuration, valve port geometry and shock absorber operating conditions.

Separate distributions are available for OpenOffice or Excel spreadsheets. Shim ReStackor uses the spreadsheet interface to present calculation results in the familiar graphical environment of a spreadsheet allowing manipulation of the outputs to show the specific performance information of interest.

Spreadsheet operation:

Run Button: Hitting the run button launches a spreadsheet macro that runs the 12,000 lines of Shim ReStackor code the reads the spreadsheet inputs and computes the shock absorber performance.

Load_Output: The load output button loads the Shim ReStackor calculation results into the "stack" and "ReStackor" tabs of the spreadsheet. All plots in the spreadsheet are updated with the new calculation results.

Edit_Output: Launches notepad to view the calculation output text file and any error messages generated.

Baseline Button: Copies the current configuration and calculation results to the "Baseline" tab and adds the orange "Baseline" curve to the plots. Comparison of future calculations to the "Baseline" allows quick evaluation of the effect of adding face shims, modifying crossover gaps or changes to the shim stack clamp diameter.

Valve port geometry

Three easily measured dimensions specify the shock absorber valve port configuration. Detailed specification of each input is given in the User Manual input section.

- **r.port:** Defines the inner radius where the valve port fluid pressure is applied to the shim stack face. The combination of r.port and d.port define the fluid pressure torque deflecting the shim stack
- **d.port:** Defines the seat length along the side of the valve port metering tangential fluid spill. The d.port seat length progressively opens as the shim stack peels back along the valve port face
- **w.port:** Defines the valve port perimeter seat length metering radial outward spill

The combination of d.port and w.port also define the valve port area limiting flow at high speed.

Valve port radial and tangential spill areas modeled by d.port and w.port

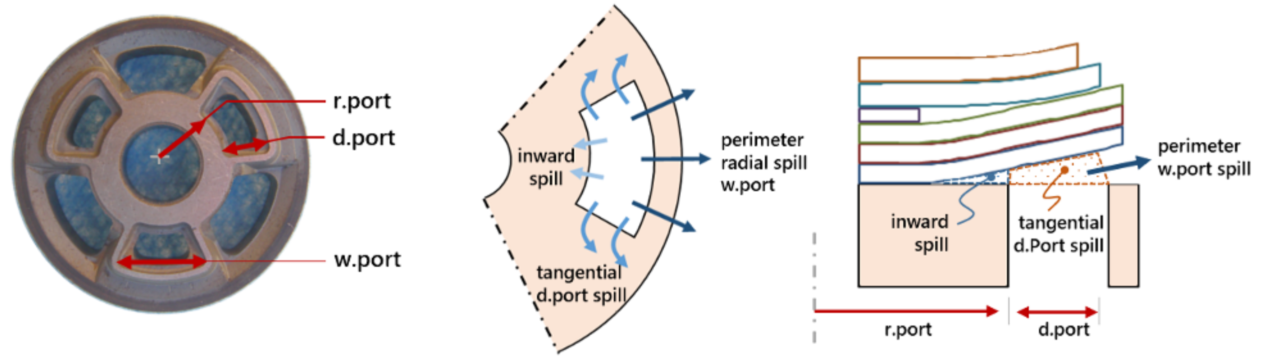
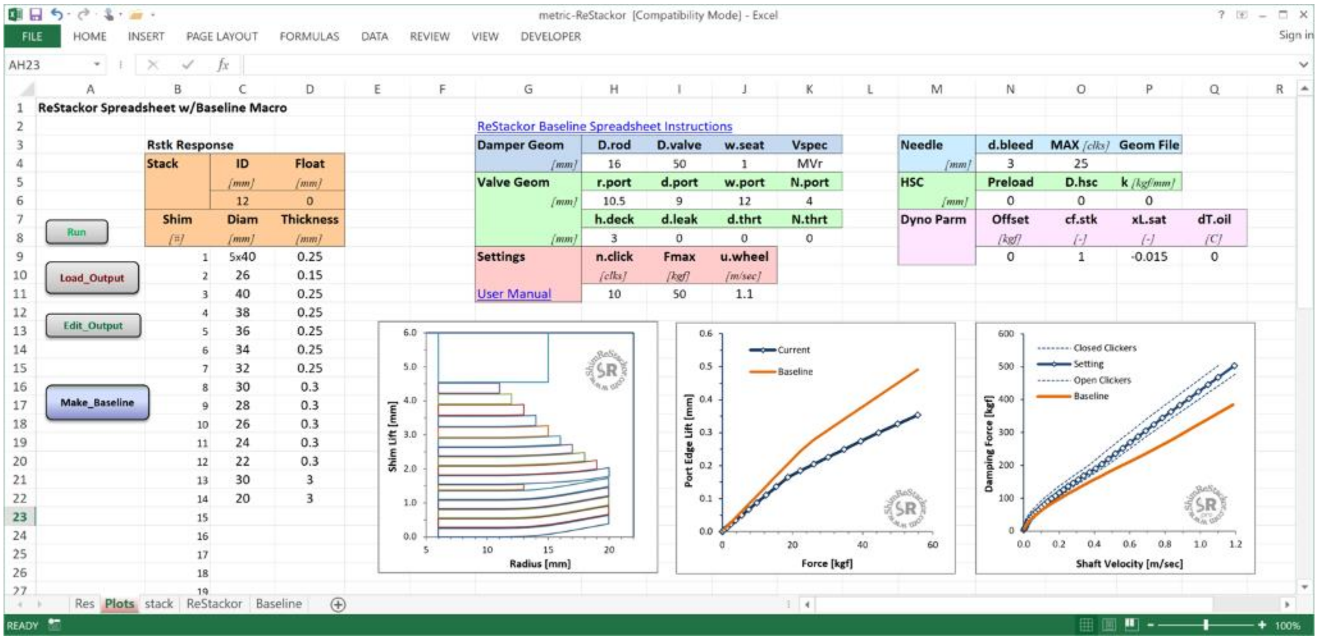


Figure 2: Three easily measured parameters define the valve port geometry

Shim stack inputs

A simple listing of shim diameters and thickness specifies the shim stack configuration in columns C and D. The shim stack deflection graphic, produced by the calculation outputs, provides a simple visual check to insure the configuration analyzed matches the intended shim stack configuration.



ReStackor Spreadsheet w/Baseline Macro

Rstk Response

Stack	ID	Float
	[mm]	[mm]
	12	0
Shim	Diam	Thickness
[#]	[mm]	[mm]
1	5x40	0.25
2	26	0.15
3	40	0.25
4	38	0.25
5	36	0.25
6	34	0.25
7	32	0.25
8	30	0.3
9	28	0.3
10	26	0.3
11	24	0.3
12	22	0.3
13	30	3
14	20	3
15		
16		
17		
18		
19		

ReStackor Baseline Spreadsheet Instructions

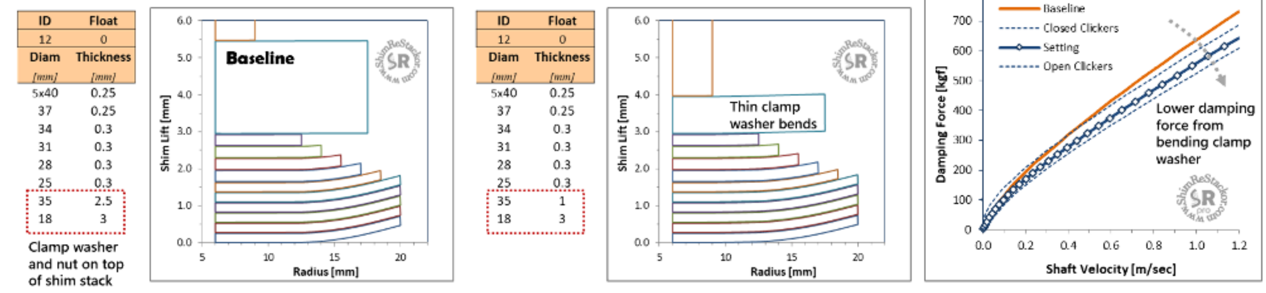
Damper Geom	D.rod	D.valve	w.seat	Vspec
[mm]	16	50	1	MVr
Valve Geom	r.port	d.port	w.port	N.port
[mm]	10.5	9	12	4
	h.deck	d.leak	d.thrt	N.thrt
[mm]	3	0	0	0
Settings	n.click	Fmax	u.wheel	
	[clks]	[kgf]	[m/sec]	
User Manual	10	50	1.1	

Needle	d.bleed	MAX [clks]	Geom File	
[mm]	3	25		
HSC	Preload	D.hsc	k [kgf/mm]	
[mm]	0	0	0	
Dyno Parm	Offset	cf.stk	xL.sat	dT.oil
	[kgf]	[-]	[-]	[C]
	0	1	-0.015	0

Spreadsheet inputs

The final two entries in the shim stack listing must specify the shim stack clamp washer and nut dimensions. Small deflections of the clamp washer at high force produce significant changes in damping force as demonstrated by the example below. For accurate results, ReStackor inputs need the actual thickness of the clamp washer and nut used in the shock absorber.

ReStackor calculations require clamp washer and nut on top of shim stack



ID	Float
12	0
Diam [mm]	Thickness [mm]
5x40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
35	2.5
18	3

Clamp washer and nut on top of shim stack

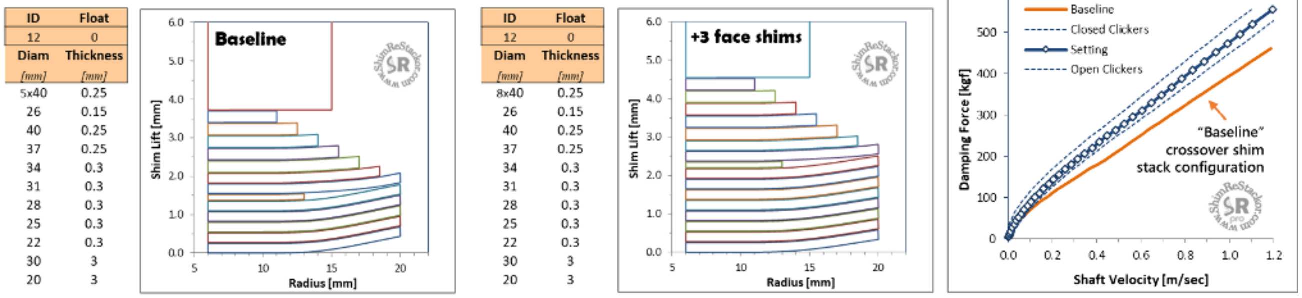
ID	Float
12	0
Diam [mm]	Thickness [mm]
5x40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
35	1
18	3

Figure 3: Small deflections in the shim stack clamp washer result in a significant damping force drop

Shim stack tuning example

The "Make_Baseline" button in Shim ReStackor spreadsheets saves the current configuration and damping performance as a reference baseline setup. The examples below compare the "Baseline" to various shim stack modifications adding additional face shims, larger clamp shim, modifying the crossover diameter/position or adding a ring shim to preload the stack.

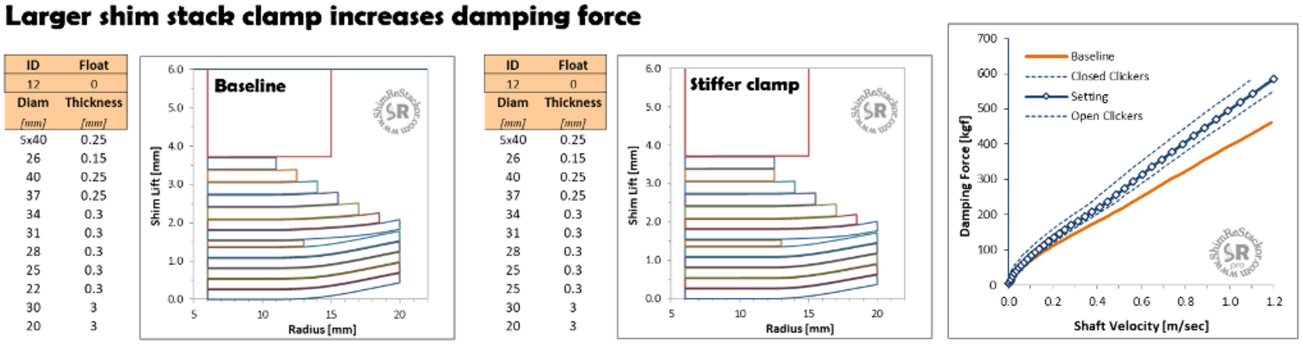
Damping force increase with three shims added to shim stack face



ID	Float
12	0
Diam [mm]	Thickness [mm]
5x40	0.25
26	0.15
40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
22	0.3
30	3
20	3

ID	Float
12	0
Diam [mm]	Thickness [mm]
8x40	0.25
26	0.15
40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
22	0.3
30	3
20	3

Larger shim stack clamp increases damping force

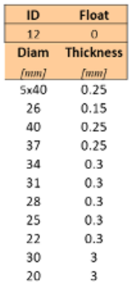


ID	Float
12	0
Diam [mm]	Thickness [mm]
5x40	0.25
26	0.15
40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
22	0.3
30	3
20	3

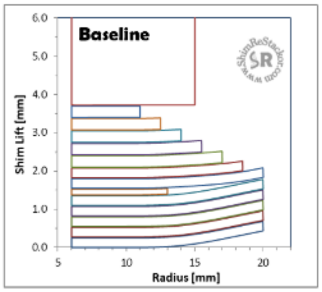
ID	Float
12	0
Diam [mm]	Thickness [mm]
5x40	0.25
26	0.15
40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
25	0.3
30	3
20	3

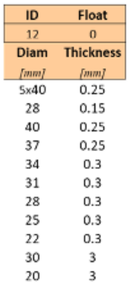
Spreadsheet inputs

Increasing crossover diameter increases high speed damping force

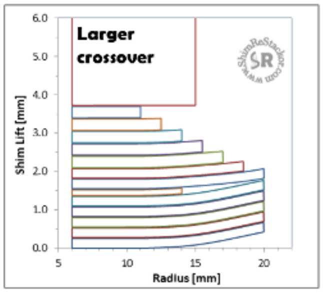


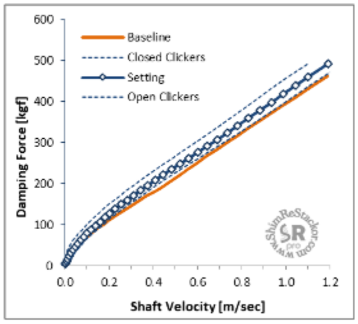
ID	Float
12	0
Diam	Thickness
[mm]	[mm]
5x40	0.25
26	0.15
40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
22	0.3
30	3
20	3



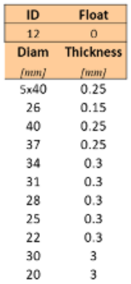


ID	Float
12	0
Diam	Thickness
[mm]	[mm]
5x40	0.25
28	0.15
40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
22	0.3
30	3
20	3

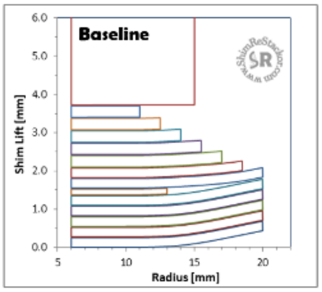


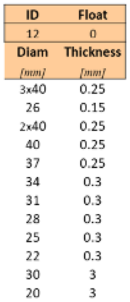


Positioning crossover closer to face reduces damping force

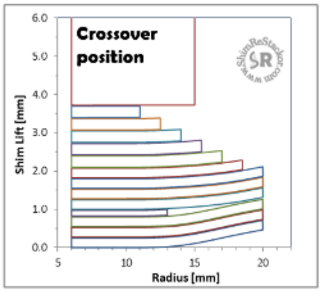


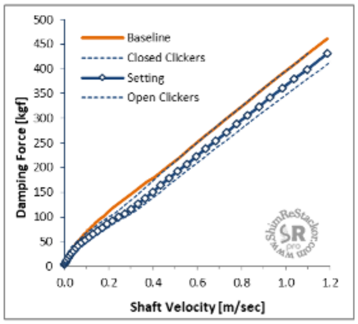
ID	Float
12	0
Diam	Thickness
[mm]	[mm]
5x40	0.25
26	0.15
40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
22	0.3
30	3
20	3



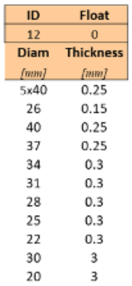


ID	Float
12	0
Diam	Thickness
[mm]	[mm]
3x40	0.25
26	0.15
2x40	0.25
40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
22	0.3
30	3
20	3

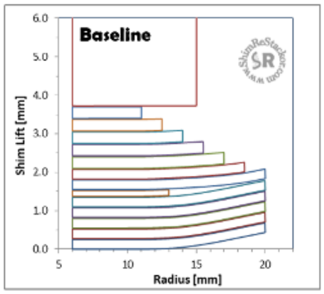




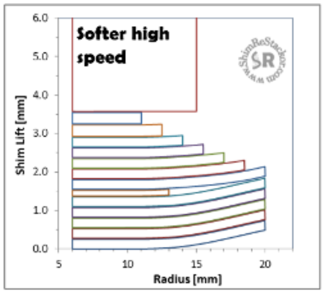
Softer high speed stack

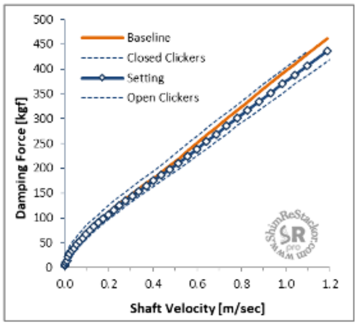


ID	Float
12	0
Diam	Thickness
[mm]	[mm]
5x40	0.25
26	0.15
40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
22	0.3
30	3
20	3

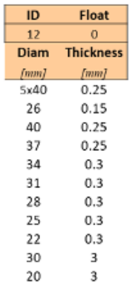


ID	Float
12	0
Diam	Thickness
[mm]	[mm]
5x40	0.25
26	0.15
40	0.25
37	0.25
34	0.25
31	0.25
28	0.25
25	0.3
22	0.3
30	3
20	3

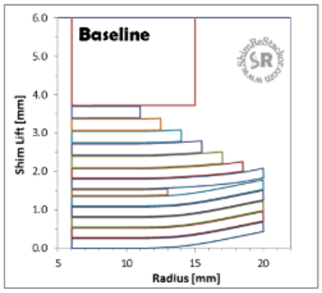


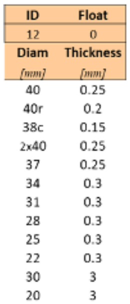


Ring-shim preload increases damping force across velocity range

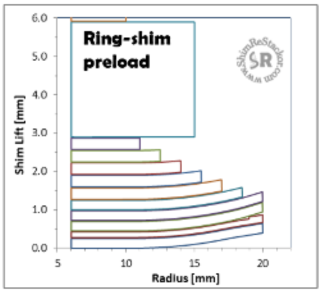


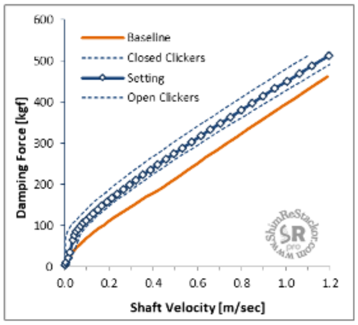
ID	Float
12	0
Diam	Thickness
[mm]	[mm]
5x40	0.25
26	0.15
40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
22	0.3
30	3
20	3





ID	Float
12	0
Diam	Thickness
[mm]	[mm]
40	0.25
40r	0.2
38c	0.15
2x40	0.25
37	0.25
34	0.3
31	0.3
28	0.3
25	0.3
22	0.3
30	3
20	3

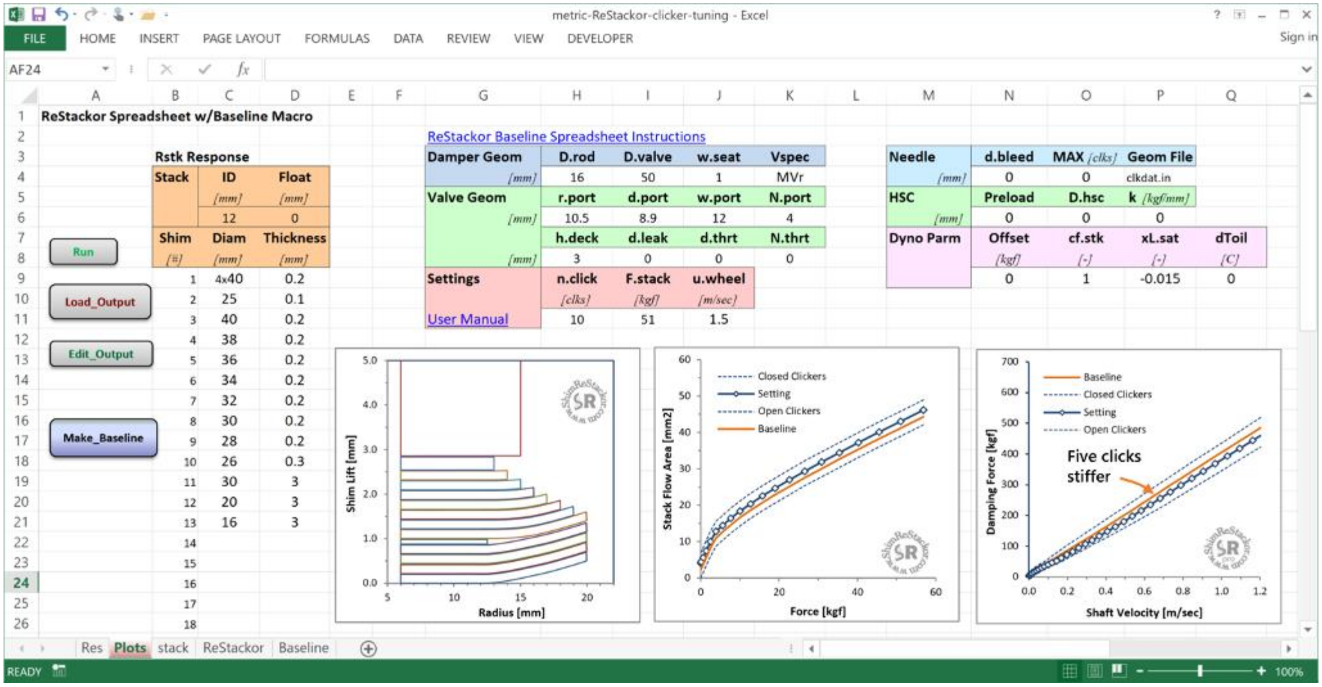




Fine tune suspension setups based on clicker settings

Sample application: Test rides show the suspension needs to be five clicks stiffer.

Running ReStackor with the clickers set five clicks stiffer gives the target damping force curve, the target curve is set as the "baseline". Details of specifying the clicker need geometry are given in the input section.



ReStackor Spreadsheet w/Baseline Macro

Rstk Response

Stack	**ID**	**Float**
	[mm]	*[mm]*
	12	0
Shim	**Diam**	**Thickness**
[#]	*[mm]*	*[mm]*
1	4x40	0.2
2	25	0.1
3	40	0.2
4	38	0.2
5	36	0.2
6	34	0.2
7	32	0.2
8	30	0.2
9	28	0.2
10	26	0.3
11	30	3
12	20	3
13	16	3
14		
15		
16		
17		
18		

ReStackor Baseline Spreadsheet Instructions

Damper Geom	**D.rod**	**D.valve**	**w.seat**	**Vspec**
[mm]	16	50	1	MVr
Valve Geom	**r.port**	**d.port**	**w.port**	**N.port**
[mm]	10.5	8.9	12	4
	h.deck	**d.leak**	**d.thrt**	**N.thrt**
[mm]	3	0	0	0
Settings	**n.click**	**F.stack**	**u.wheel**	
	[clks]	*[kgf]*	*[m/sec]*	
User Manual	10	51	1.5	

Needle	**d.bleed**	**MAX** *[clks]*	**Geom File**	
[mm]	0	0	clkdat.in	
HSC	**Preload**	**D.hsc**	**k** *[kgf/mm]*	
[mm]	0	0	0	
Dyno Parm	**Offset**	**cf.stk**	**xL.sat**	**dToil**
	[kgf]	*[-]*	*[-]*	*[C]*
	0	1	-0.015	0

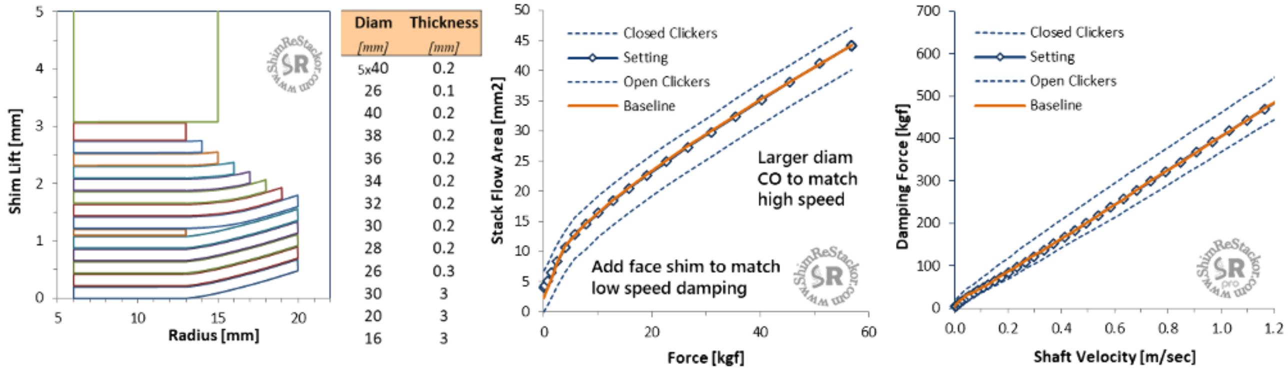
Stiffening the high speed stack matches the target damping force at high speed, but low speed damping is too soft.

Adding face shims matches low speed damping, but does not produce the damping force increase needed at high speed.

Hacking around on the shim stack shows adding a face shim and increasing the crossover shim diameter produces the best match to the target damping force curve at both low and high speed.

Tuning shim stacks in terms of clicker settings allows the suspension setup to be fine tuned in terms of the real-world forces you can actually "feel" when you ride. Damping force curves can be reshaped to be three clicks softer at low speed and five clicks stiffer at high speed or any other combination of settings determined from test rides of the setup.

Shim stack tuned five clicks stiffer across shaft velocity range



Diam	**Thickness**
[mm]	*[mm]*
5x40	0.2
26	0.1
40	0.2
38	0.2
36	0.2
34	0.2
32	0.2
30	0.2
28	0.2
26	0.3
30	3
20	3
16	3

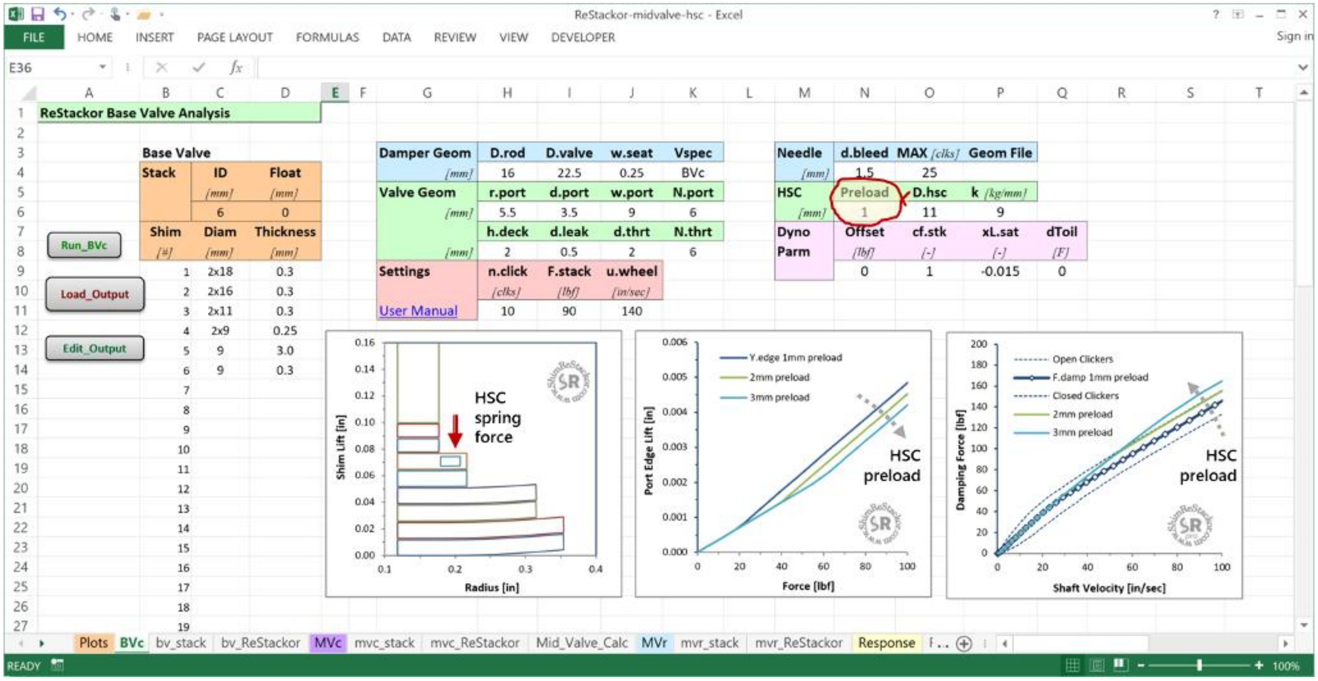
High speed compression adjuster

The high speed compression adjuster (HSC) adds spring preload to the shim stack. The HSC input block specifies the spring preload, shim diameter where the spring force is applied to the stack and the HSC spring stiffness.

The HSC spring stiffness can be estimated from measurements of the spring coil wire diameter.

Calculation outputs draw a box on the shim stack indicating the location where the HSC spring force is applied. The box gives a visual check to insure the HSC force is applied at the intended location and serves as a reminder the HSC system is active on the shim stack.

Increasing HSC spring preload (cranking down on the compression adjuster) increases damping force and changes the shaft velocity where the HSC spring force kicks in to increase damping force.



ReStackor Base Valve Analysis

Base Valve

Stack	ID	Float
	[mm]	[mm]
	6	0
Shim	**Diam**	**Thickness**
[#]	[mm]	[mm]
1	2x18	0.3
2	2x16	0.3
3	2x11	0.3
4	2x9	0.25
5	9	3.0
6	9	0.3
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		

Damper Geom	D.rod	D.valve	w.seat	Vspec
[mm]	16	22.5	0.25	BVc
Valve Geom	r.port	d.port	w.port	N.port
[mm]	5.5	3.5	9	6
	h.deck	d.leak	d.thrt	N.thrt
[mm]	2	0.5	2	6
Settings	n.click	F.stack	u.wheel	
	[clks]	[lbf]	[in/sec]	
User Manual	10	90	140	

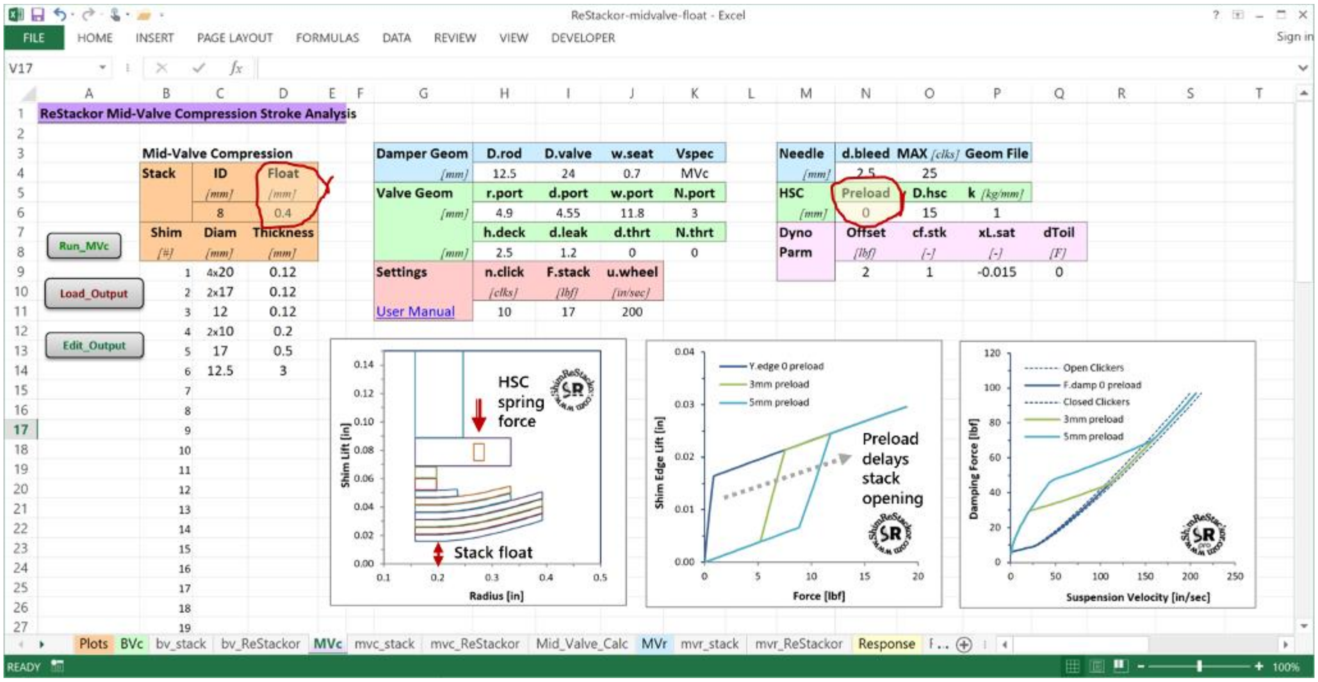
Needle	d.bleed	MAX [clks]	Geom File	
[mm]	1.5	25		
HSC	Preload	D.hsc	k [kg/mm]	
[mm]	1	11	9	
Dyno	Offset	cf.stk	xL.sat	dToil
Parm	[lbf]	[-]	[-]	[F]
	0	1	-0.015	0

Shim stack float

The shim stack float input is at the top of the shim stack listing in column D. The rate of float opening is controlled by installing an HSC spring on top of the stack to act as a check spring. Stiffness of the HSC spring controls the rate of float opening and the spring preload controls the cracking pressure.

The example below demonstrates a floated shim stack run with a progressive increase in spring preload to increase the cracking pressure and compression damping force at low speed.

Spreadsheet inputs



ReStackor Mid-Valve Compression Stroke Analysis

Mid-Valve Compression

Stack	ID [mm]	Float [mm]
	8	0.4

Shim [#]	Diam [mm]	Thickness [mm]
1	4x20	0.12
2	2x17	0.12
3	12	0.12
4	2x10	0.2
5	17	0.5
6	12.5	3
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		

Damper Geom	D.rod	D.valve	w.seat	Vspec
[mm]	12.5	24	0.7	MVc
Valve Geom	r.port	d.port	w.port	N.port
[mm]	4.9	4.55	11.8	3
	h.deck	d.leak	d.thrt	N.thrt
[mm]	2.5	1.2	0	0
Settings	n.click [clks]	F.stack [lbf]	u.wheel [in/sec]	
User Manual	10	17	200	

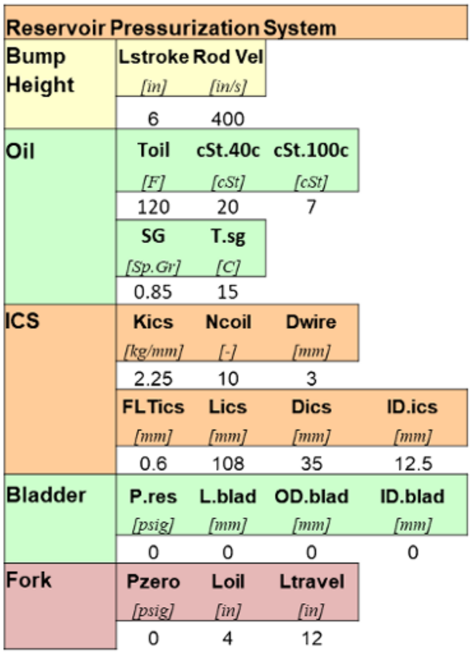
Needle	d.bleed	MAX [clks]	Geom File	
[mm]	2.5	25		
HSC	Preload	D.hsc	k [kg/mm]	
[mm]	0	15	1	
Dyno Parm	Offset [lbf]	cf.stk [-]	xL.sat [-]	dToil [F]
	2	1	-0.015	0

Pressurization systems

The ICS (Inner Chamber Spring) pressurization system inputs are on the "Res" tab of Shim ReStackor spreadsheets. Inputs describe the ICS spring stiffness (Kics), the number of coils (Ncoil) and spring wire diameter (Dwire).

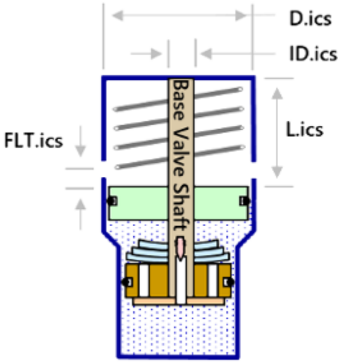
Shim ReStackor uses the number of coils and wire diameter to determine the ICS coil bind length. Cavitation events can push the ICS piston beyond the coil bind length, which cracks plastic ICS pistons.

Detailed specifications for each input parameter are given in the User Manual input section.



Reservoir Pressurization System				
Bump Height	Lstroke [in]	Rod Vel [in/s]		
	6	400		
Oil	Toil [F]	cSt.40c [cSt]	cSt.100c [cSt]	
	120	20	7	
	SG [Sp.Gr]	T.sg [C]		
	0.85	15		
ICS	Kics [kg/mm]	Ncoil [-]	Dwire [mm]	
	2.25	10	3	
	FLTics [mm]	Lics [mm]	Dics [mm]	ID.ics [mm]
	0.6	108	35	12.5
Bladder	P.res [psig]	L.blad [mm]	OD.blad [mm]	ID.blad [mm]
	0	0	0	0
Fork	Pzero [psig]	Loil [in]	Ltravel [in]	
	0	4	12	

Inner chamber spring (ICS) pressurization system



N.Coil [=] Number of ICS spring coils
D.Wire [=] ICS spring wire diameter

Spreadsheet inputs

The ICS inputs allow float on the spring (FLTics). Lics describes the chamber length and gas force operating on the ICS piston for closed chamber systems. Dics describes the ICS piston diameter and ID.ics describes the shaft diameter running through the ICS piston, which holds the base valve. The combination of Dics and ID.ics describe the piston face area and the transfer of ICS piston force to shock chamber pressure.

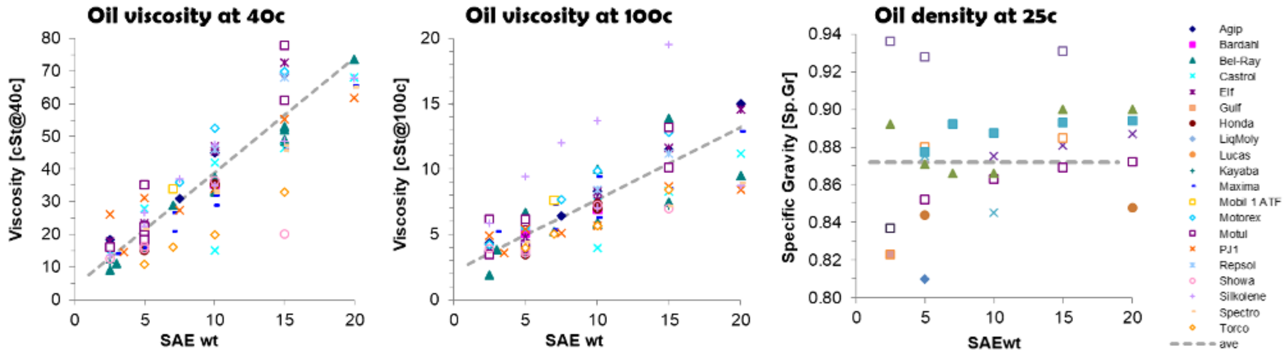
Oil viscosity

Shock oil property inputs use the manufacturer spec's for centistoke viscosity at 40 and 100 centigrade coupled with the oil specific gravity SG (or g/cc density) at the reference temperature T.sg specified by the manufacturer.

Shim ReStackor uses the combination of centistoke viscosity and oil density to determine the true dynamic viscosity of the oil. Shim ReStackor uses the Andrade equation to define the effect of oil temperature on oil viscosity and the shock absorber damping force at the input shock absorber operating temperature specified by Toil.

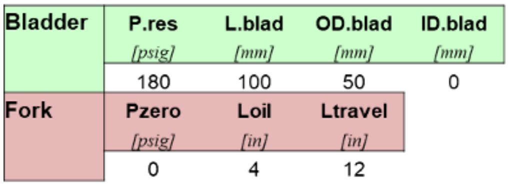
Manufacture oil viscosity and density data compiled by Peter Verdone shows SAE 5 wt oil varies over a significant range emphasizing the importance of entering the actual suspension oil properties to determine the true damping performance of the shock absorber.

Manufacturer suspension oil viscosity complied by Peter Verdone



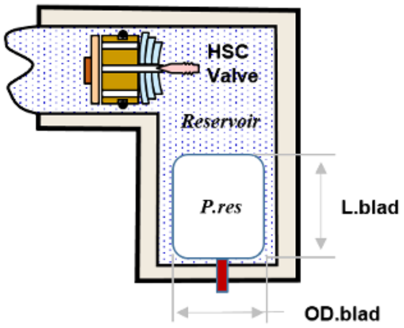
Gas reservoir bladder

The gas reservoir bladder inputs specify the bladder initial pressure (P.res), bladder length (L.blad) and bladder diameter (OD.blad). The L.blad and OD.blad inputs specify the bladder volume, which in turn specifies the change in pressure as the bladder is compressed through the shock absorber stroke. Forks with a gas bladder use the ID.blad input to describe the shaft diameter running through the bladder and the corresponding reduction in bladder volume.



Bladder	P.res	L.blad	OD.blad	ID.blad
	[psig]	[mm]	[mm]	[mm]
	180	100	50	0
Fork	**Pzero**	**Loil**	**Ltravel**	
	[psig]	[in]	[in]	
	0	4	12	

Gas reservoir bladder

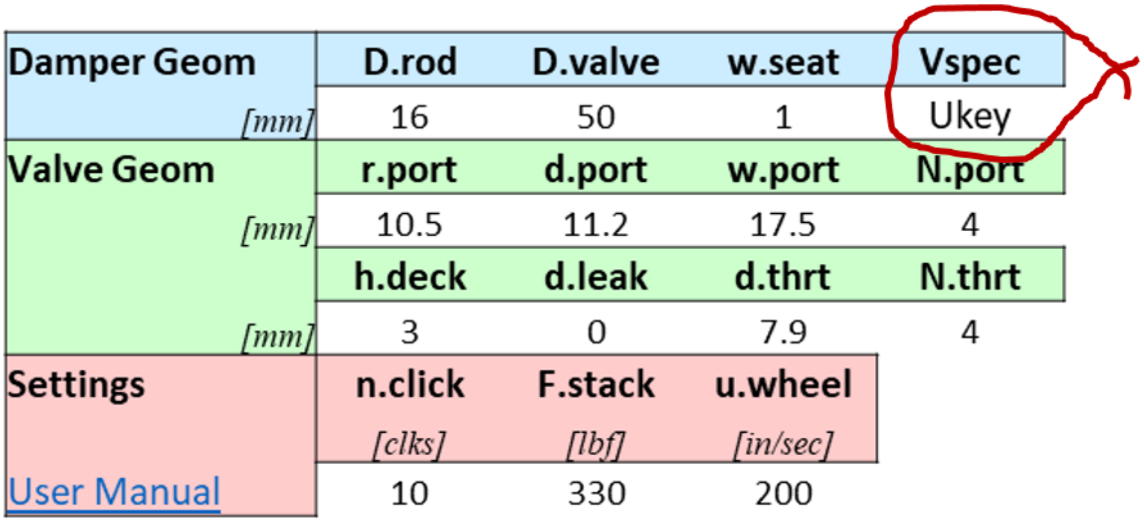


Fork gas spring

The fork input block defines the fork bleed pressure at full extension (Pzero), the oil level measured at full compression (Loil) and the fork travel. Those three inputs describe the fork gas pressure and gas spring force through the suspension travel.

Shim ReStackor code key

- Extract User key from demo
- Install code key purchased through PayPal



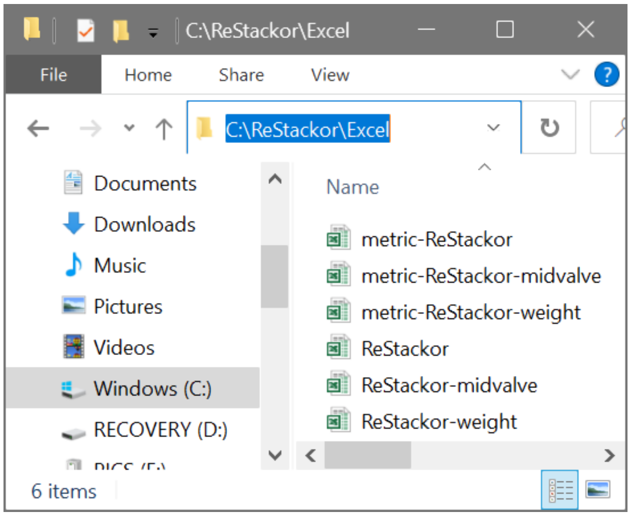
Damper Geom	D.rod	D.valve	w.seat	Vspec
[mm]	16	50	1	Ukey
Valve Geom	r.port	d.port	w.port	N.port
[mm]	10.5	11.2	17.5	4
	h.deck	d.leak	d.thrt	N.thrt
[mm]	3	0	7.9	4
Settings	n.click	F.stack	u.wheel	
	[clks]	[lbf]	[in/sec]	
User Manual	10	330	200	

Shim ReStackor demo

The Shim ReStackor demo installs the calculation spreadsheets on the C: drive:

- C:\ReStackor\Excel
- C:\ReStackor\OpenOffice

The demo spreadsheets can be copied from the C: drive directory and run from any directory on the computer.



metric-ReStackor
metric-ReStackor-midvalve
metric-ReStackor-weight
ReStackor
ReStackor-midvalve
ReStackor-weight

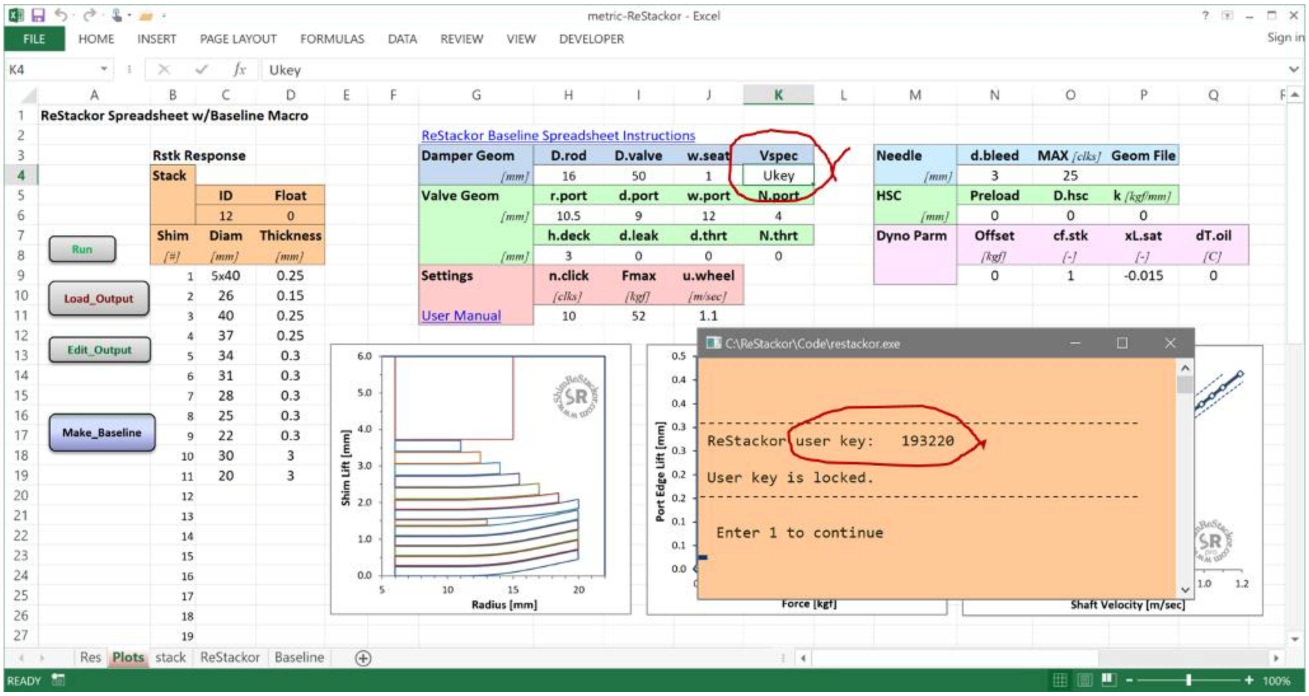
User key

All Shim ReStackor spreadsheets use the input keyword Vspec to specify the shock absorber stroke. Normal inputs are:

- BVc: Base valve compression stroke
- MVc: Mid-valve compression stroke
- MVr: Mid-valve rebound stroke

Changing the Vspec keyword to Ukey and hitting the run button instructs the calculations to extract and display your unique User key in the pop-up execution window.

All spreadsheets access and display the same User key.



Ukey

ReStackor Spreadsheet w/Baseline Macro

Rstk Response

Stack	ID	Float
	12	0
Shim [#]	**Diam** [mm]	**Thickness** [mm]
1	5x40	0.25
2	26	0.15
3	40	0.25
4	37	0.25
5	34	0.3
6	31	0.3
7	28	0.3
8	25	0.3
9	22	0.3
10	30	3
11	20	3
12		
13		
14		
15		
16		
17		
18		
19		

ReStackor Baseline Spreadsheet Instructions

Damper Geom	**D.rod**	**D.valve**	**w.seat**	**Vspec**
[mm]	16	50	1	Ukey
Valve Geom	**r.port**	**d.port**	**w.port**	**N.port**
[mm]	10.5	9	12	4
	h.deck	**d.leak**	**d.thrt**	**N.thrt**
[mm]	3	0	0	0
Settings	**n.click** [clks]	**Fmax** [kgf]	**u.wheel** [m/sec]	
User Manual	10	52	1.1	

Needle	**d.bleed**	**MAX** [clks]	**Geom File**	
[mm]	3	25		
HSC	**Preload**	**D.hsc**	**k** [kgf/mm]	
[mm]	0	0	0	
Dyno Parm	**Offset** [kgf]	**cf.stk** [-]	**xL.sat** [-]	**dT.oil** [C]
	0	1	-0.015	0

C:\ReStackor\Code\restackor.exe

```
-----------------------------------------------------------
ReStackor user key:   193220

User key is locked.
-----------------------------------------------------------

 Enter 1 to continue
```

Purchase a code key

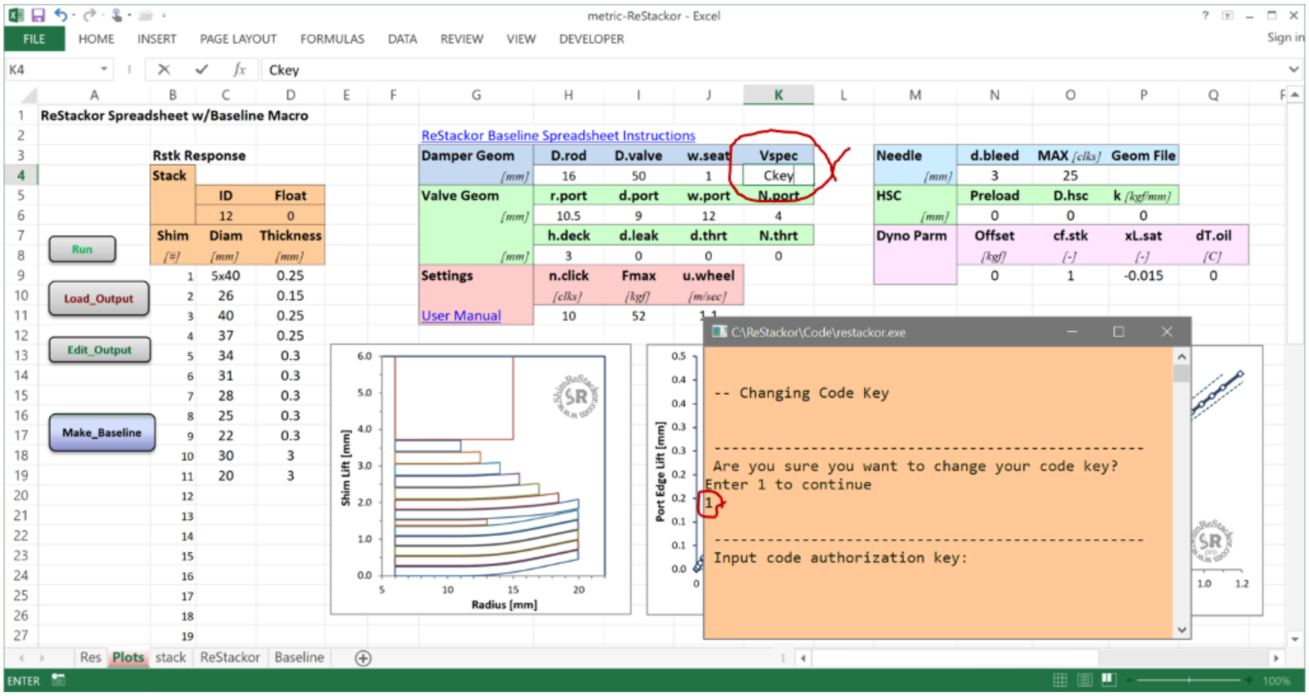
To purchase a code key enter your unique User key on the Shim ReStackor web site “BuyNow” tab. Hitting the “Buy Now” button takes you to the PayPal web site to complete your transaction.

On completion of the PayPal process, your Shim ReStackor code key is emailed to the address entered at PayPal. Unfortunately, unsolicited emails sent to your inbox frequently end up in the “junk mail” folder. If your code key does not arrive in a couple of minutes check the “junk mail” folders.

Entering your code key

Set the Vspec keyword to “Ckey”. Hitting the run button instructs the pop-up execution window to prompt you to enter your code key.

After entering your code key, all Shim ReStackor spreadsheets will be authorized to run at the code level purchased through PayPal.



K4 Ckey

ReStackor Spreadsheet w/Baseline Macro

Rstk Response

Stack	ID	Float
	12	0

Shim [#]	Diam [mm]	Thickness [mm]
1	5x40	0.25
2	26	0.15
3	40	0.25
4	37	0.25
5	34	0.3
6	31	0.3
7	28	0.3
8	25	0.3
9	22	0.3
10	30	3
11	20	3
12		
13		
14		
15		
16		
17		
18		
19		

Damper Geom	D.rod	D.valve	w.seat	Vspec
[mm]	16	50	1	Ckey
Valve Geom	r.port	d.port	w.port	N.port
[mm]	10.5	9	12	4
	h.deck	d.leak	d.thrt	N.thrt
[mm]	3	0	0	0
Settings	n.click [clks]	Fmax [kgf]	u.wheel [m/sec]	
User Manual	10	52	1.1	

Needle	d.bleed	MAX [clks]	Geom File	
[mm]	3	25		
HSC	Preload	D.hsc	k [kgf/mm]	
[mm]	0	0	0	
Dyno Parm	Offset [kgf]	cf.stk [-]	xL.sat [-]	dT.oil [C]
	0	1	-0.015	0

C:\ReStackor\Code\restackor.exe

```
 -- Changing Code Key



 ---------------------------------------------------
 Are you sure you want to change your code key?
Enter 1 to continue
1

 ---------------------------------------------------
 Input code authorization key:
```

Code run levels

Purchasing a Shim ReStackor pro license enables damping force calculations in all spreadsheets.

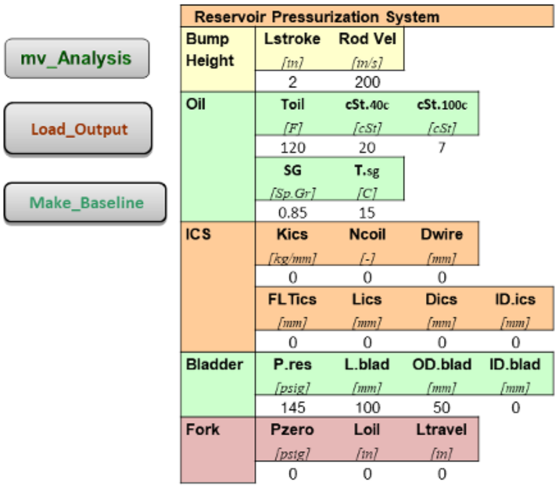
The Suspension Response add-on enables response calculations on the ReStackor-midvalve spreadsheet. Response calculations compute the suspension bottoming velocity, rebound response and force over stroke calculations on the response tab of mid-valve spreadsheets

Mid-Valve Spreadsheet

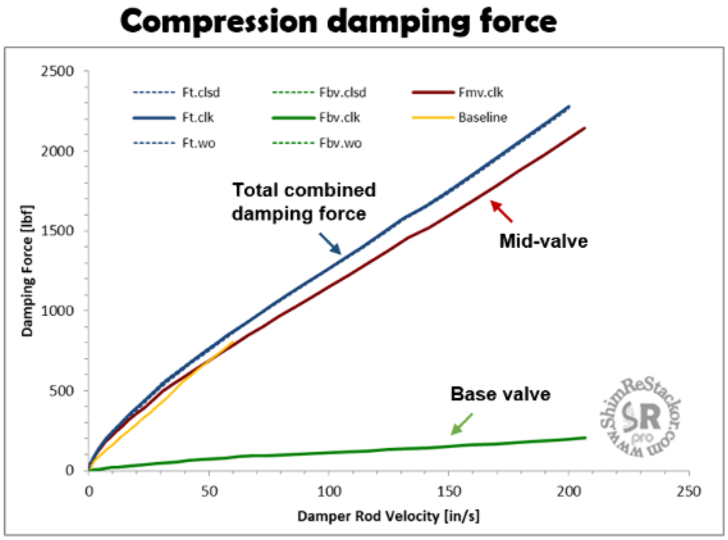
- Fork
  - Combined compression damping force of base and mid-valve

- Shock
  - Combined compression damping force of compression adjuster and mid-valve

- Tune backpressure to pressure balance chambers and suppress cavitation oil foaming



Reservoir Pressurization System				
Bump Height	Lstroke *[in]*	Rod Vel *[m/s]*		
	2	200		
Oil	Toil *[F]*	cSt.40c *[cSt]*	cSt.100c *[cSt]*	
	120	20	7	
	SG *[Sp.Gr]*	T.sg *[C]*		
	0.85	15		
ICS	Kics *[kg/mm]*	Ncoil *[-]*	Dwire *[mm]*	
	0	0	0	
	FLTics *[mm]*	Lics *[mm]*	Dics *[mm]*	ID.ics *[mm]*
	0	0	0	0
Bladder	P.res *[psig]*	L.blad *[mm]*	OD.blad *[mm]*	ID.blad *[mm]*
	145	100	50	0
Fork	Pzero *[psig]*	Loil *[in]*	Ltravel *[in]*	
	0	0	0	



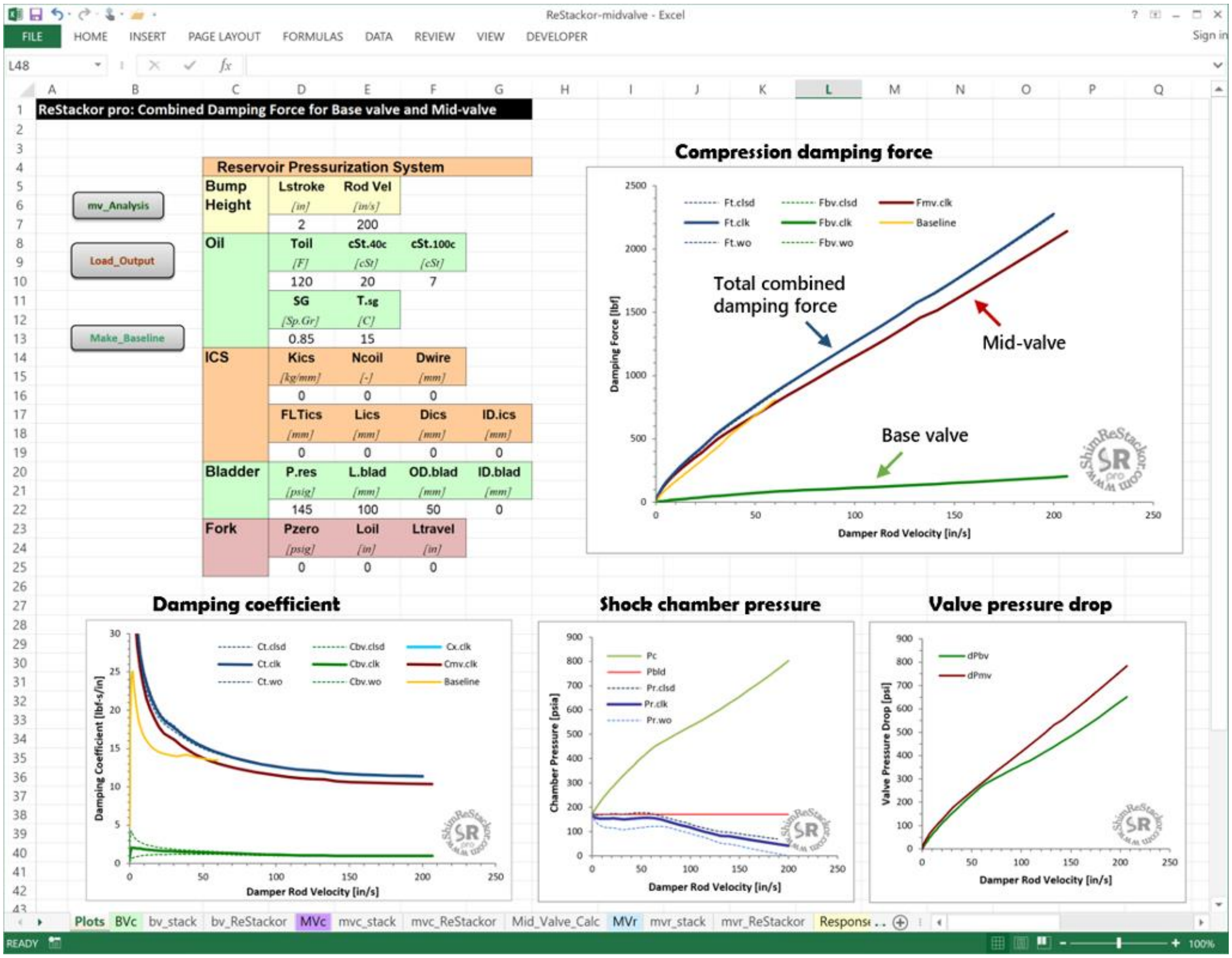
Mid-Valve Spreadsheet

The mid-valve spreadsheet contains separate tabs for the base valve, mid-valve and rebound damping strokes. The three tabs define damping force from each of the three valves in a shock absorber and give a complete description of shock absorber performance in a single spreadsheet. Inputs on each tab are the same as those described for the "basic" ReStackor.xls spreadsheet.

The "mv_Analysis" macro button on the Plots tab of ReStackor-midvalve.xls spreadsheets combines the damping force of the base valve and mid-valve to determine the combined compression damping force including the effects of cavitation.

Under non-cavitating conditions, the overall compression damping force is simply the sum of the base plus mid-valve. Under cavitating conditions, oil foaming alters the fluid flow through the shock absorber circuits driving damping force up or down depending on the severity of cavitation.

The purpose of the mid-valve spreadsheet is tuning fork base valves or shock compression adjusters to control backpressure on the shock chambers and suppress cavitation. Tuning backpressures to suppress cavitation is known as "pressure balancing" the shock.



ReStackor pro: Combined Damping Force for Base valve and Mid-valve

Reservoir Pressurization System				
Bump Height	**Lstroke** [in]	**Rod Vel** [in/s]		
	2	200		
Oil	**Toil** [F]	**cSt.40c** [cSt]	**cSt.100c** [cSt]	
	120	20	7	
	SG [Sp.Gr]	**T.sg** [C]		
	0.85	15		
ICS	**Kics** [kg/mm]	**Ncoil** [-]	**Dwire** [mm]	
	0	0	0	
	FLTics [mm]	**Lics** [mm]	**Dics** [mm]	**ID.ics** [mm]
	0	0	0	0
Bladder	**P.res** [psig]	**L.blad** [mm]	**OD.blad** [mm]	**ID.blad** [mm]
	145	100	50	0
Fork	**Pzero** [psig]	**Loil** [in]	**Ltravel** [in]	
	0	0	0	

Shock chamber pressure

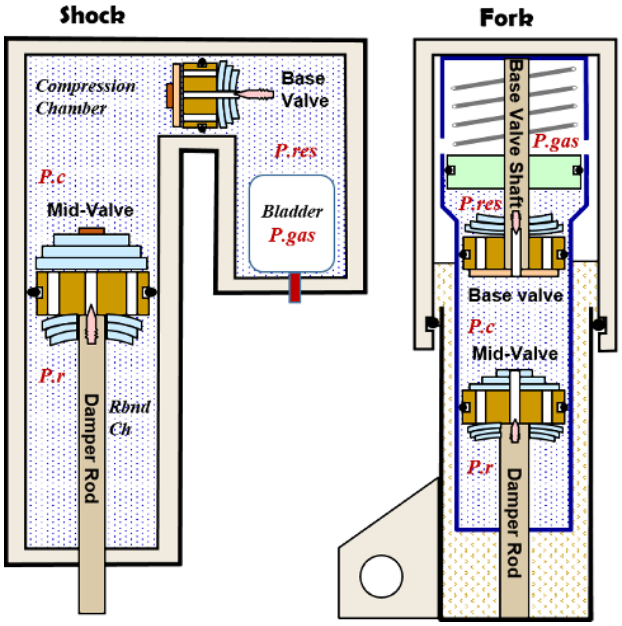
On the shock absorber compression stroke, the shaft volume entering the shock body forces an equal volume of fluid out of the shock through the base valve into the oil reservoir.

The shock gas reservoir pressure plus the pressure drop across the base valve defines the fluid pressure in the compression chamber, Pc. The compression chamber pressure acting on the damper rod area defines the base valve damping force. At zero velocity, the force of the gas reservoir pressure acting on the damper rod defines the shock absorber gas spring force.

Motion of the main piston during the compression stroke forces fluid through the mid-valve into the rebound chamber. The pressure drop across the mid-valve subtracted from the compression chamber pressure defines the rebound chamber pressure. Pr= Pc –dP.mv.

Cavitation

If the piston pressure drop on the compression stroke is greater than the compression chamber pressure (P.c) the pressure in the rebound chamber is driven to vacuum. Vacuum allows gas dissolved in the suspension oil to boil out, foaming the oil and causing a cavitation event. Cavitation initiates when the chamber pressure falls below the dissolved gas saturation pressure, typically set by the gas reservoir pressure.



Shock chamber pressure

- **P.res:** Set by initial pressure and compression of bladder or ICS spring
- **P.c:** Set by base valve pressure drop
  - $P_c = P_{res} + \Delta P_{bv}$
- **P.r:** Set by mid-valve pressure drop
  - $P_r = P_c - \Delta P_{mid-valve}$

Dissolved gas

Suspension oil contains 10% by volume dissolved gas. Pulling a vacuum on a freshly opened bottle of suspension fluid allows the dissolved gas to boil out severally foaming the oil as demonstrated by Ride Concepts Calgary.

When installed in a shock, gas slowly diffuses through the bladder, or around the o-ring seals of a piston reservoir, to saturate the oil with pressurized gas after about four months.

Vacuum degassing, Ride Concepts Calgary

Dissolved gas in the shock absorber oil at the reservoir pressure of 150 psi (10 atm) expanded back to atmospheric pressure produces a 10:1 volume expansion making the dissolved gas 100% gas by volume, which severely foams the oil. Further expanding the gas to vacuum produces an infinite volume.

Dissolved gas makes suspension oil behave like a hot bottle of Coca-Cola. Keep the cap on and the fluid behaves like a liquid. Crack the cap and the pressure drop allows the dissolved gas to boil out making the fluid a foamy mess.

Oil foaming is caused by dissolved gas. The foaming initiates whenever the fluid pressure drops below the dissolved gas pressure set by the reservoir gas pressure.

Cavitation severity

The impact of cavitation oil foaming on shock absorber performance is not widely understood. To demonstrate the severity and occurrence of cavitation oil foaming in a shock absorber Roehrig posted a video.

The problem with cavitation is when the shock flips around into the rebound stroke. The foamed oil in the rebound chamber allows the piston is just winging back through the foamed out oil producing zero rebound damping force.

The problem with cavitation isn't loss of compression damping, it is loss of rebound.

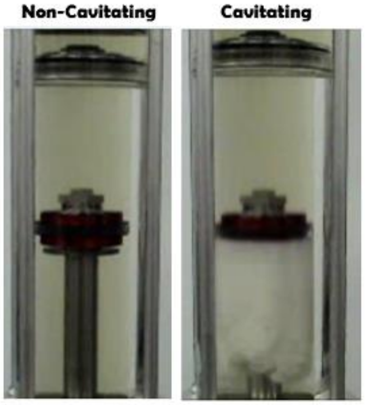
Shock pressure balancing

The cure for cavitation is simple: Adjust the base valve, or compression adjuster, to backpressure the shock and match the pressure drop across the mid-valve. Tuning shock absorber valves to match pressure drops and suppresses rebound chamber oil foaming is known as pressure balancing the shock.

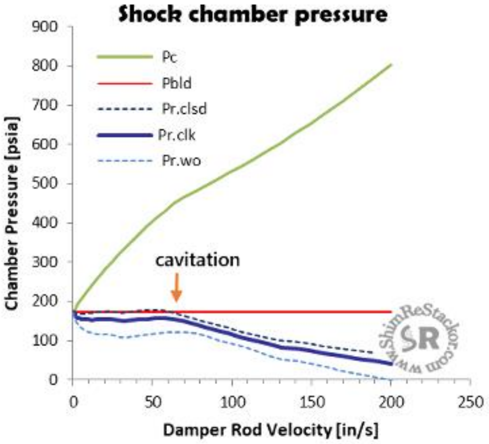
Pressure balancing is easy with Shim ReStackor. The calculations compute pressures in each chamber of the shock. Pressure balancing simply requires hacking around on the base valve, or compression adjuster, shim stacks to keep the rebound chamber (blue line) pressurized at or above the gas reservoir pressure (red line).

Keeping the rebound chamber pressurized at the initial reservoir pressure prevents the dissolved gas from boiling out of the fluid. That is equivalent to keeping the cap on a hot bottle of Coca-Cola to prevent foaming.

Low rebound chamber pressure causes oil foaming



Shock chamber pressure



The example above keeps the rebound chamber pressurized up to shaft velocities of 60 in/sec. When pushed beyond 60 in/sec the increase in pressure drop across the mid-valve causes pressures in the rebound chamber to drop. The drop in pressure allows the dissolved gas to boil out and foam the oil.

To fix the problem the compression adjuster needs to produce more backpressure above 60 in/sec. That requires hacking around on the compression adjuster shim stack to prevent the rebound chamber pressures from falling off.

Ideally, fork base valves or compression adjusters are tuned to produce a constant rebound chamber pressure equal to the gas reservoir pressure across the entire range of stroke velocities. Matching the gas reservoir pressure is the minimum pressure required to keep gas dissolved from boiling out. Maintaining rebound chamber pressures at that value reduces ware and seal drag on the rebound chamber shaft seal.

However, the shock absorber damping force in rebound is approximately double the value of compression. The higher rebound damping force produces chamber pressures of 700 psi in ReStackor calculations, approximately four times the gas reservoir pressure. Tuning compression adjusters or fork base valves to produce pressures higher than the gas reservoir pressure has little impact on seal ware.

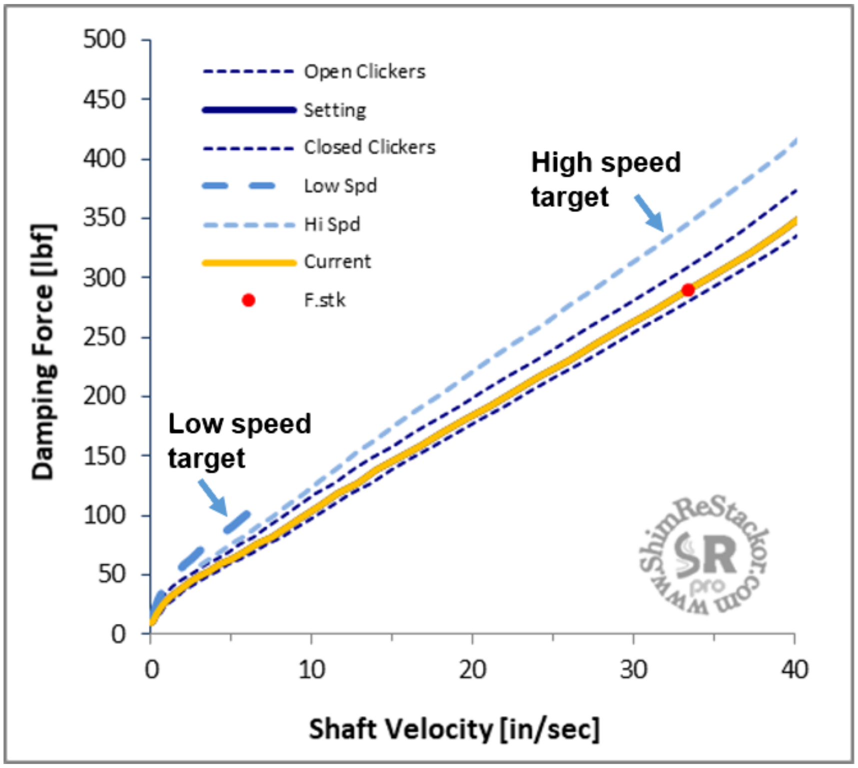
Cavitation feature

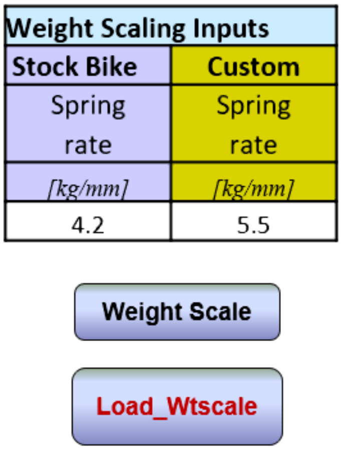
Loss of rebound damping due to cavitating the rebound chamber is obviously undesirable. However, lower rebound damping can be made into a feature accelerating the rebound stroke to get the wheels back on the ground faster after a hard hit that has deflected the chassis.

However, the loss of rebound damping on a hard hit can become a snake bite when the shock mistakes a whoop face impact for a hard hit and lets go of rebound.

Weight Scaling Spreadsheet

- Correct damping for a change in rider weight or spring rate change





Weight Scaling Inputs	
Stock Bike	**Custom**
Spring rate	Spring rate
[kg/mm]	*[kg/mm]*
4.2	5.5

Weight scaling physics

Spring-mass-damper theory defines two parameters that control suspension performance: Tau and Zeta.

Tau

Tau defines the time required for the suspension to return to race sag.

Tau is defined as the ratio of mass to spring rate. Selecting spring rate to hit a target value of race-sag sets the ratio of mass to spring rate. Matching race sag between riders of different weight sets the value of tau to the same constant value.

Zeta

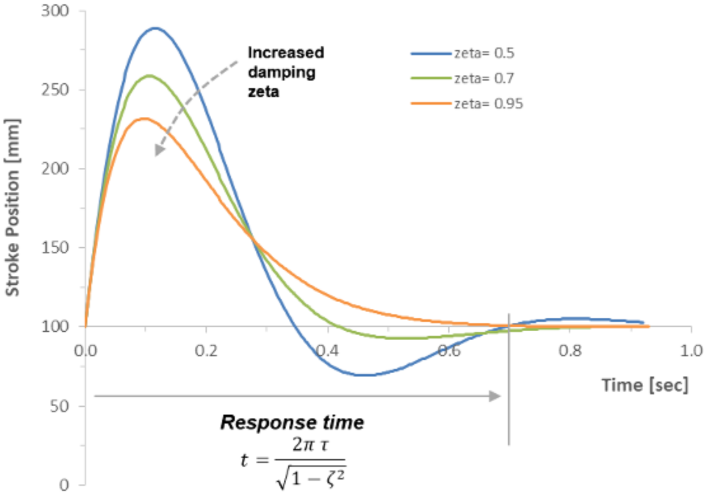
Zeta defines damping. Zeta is also a function of mass and spring rate, and adds the third parameter of damping.

The two parameters Tau and Zeta completely define suspension motion and performance. Two riders of different weights, on different bikes with different spring rates will have exactly the same suspension response, retracing the curves below, if the values of tau and zeta are set to be the same.

That fact from spring-mass-damper theory provides a powerful suspension tuning tool known as weight scaling. Matching the value of tau and zeta allows scaling of suspension performance over a wide range of conditions.

- Suspension performance can be scaled from one bike to another
- Stock suspension performance can be corrected for changes in rider weight and spring rate to preserve the suspension response, "feel" and behavior the manufacture intended

Spring-mass-damper theory describes suspension response in terms of tau and zeta



Stroke position at time (t)

$$(\zeta < 1)\quad y(t) = \frac{Imp}{\tau\sqrt{1-\zeta^2}}\,e^{\frac{-\zeta t}{\tau}}\,sin\left(\sqrt{1-\zeta^2}\,\frac{t}{\tau}\right)$$

response time (tau) $\tau = \sqrt{\frac{1}{9{,}800}\frac{m}{k_{spring}}}$

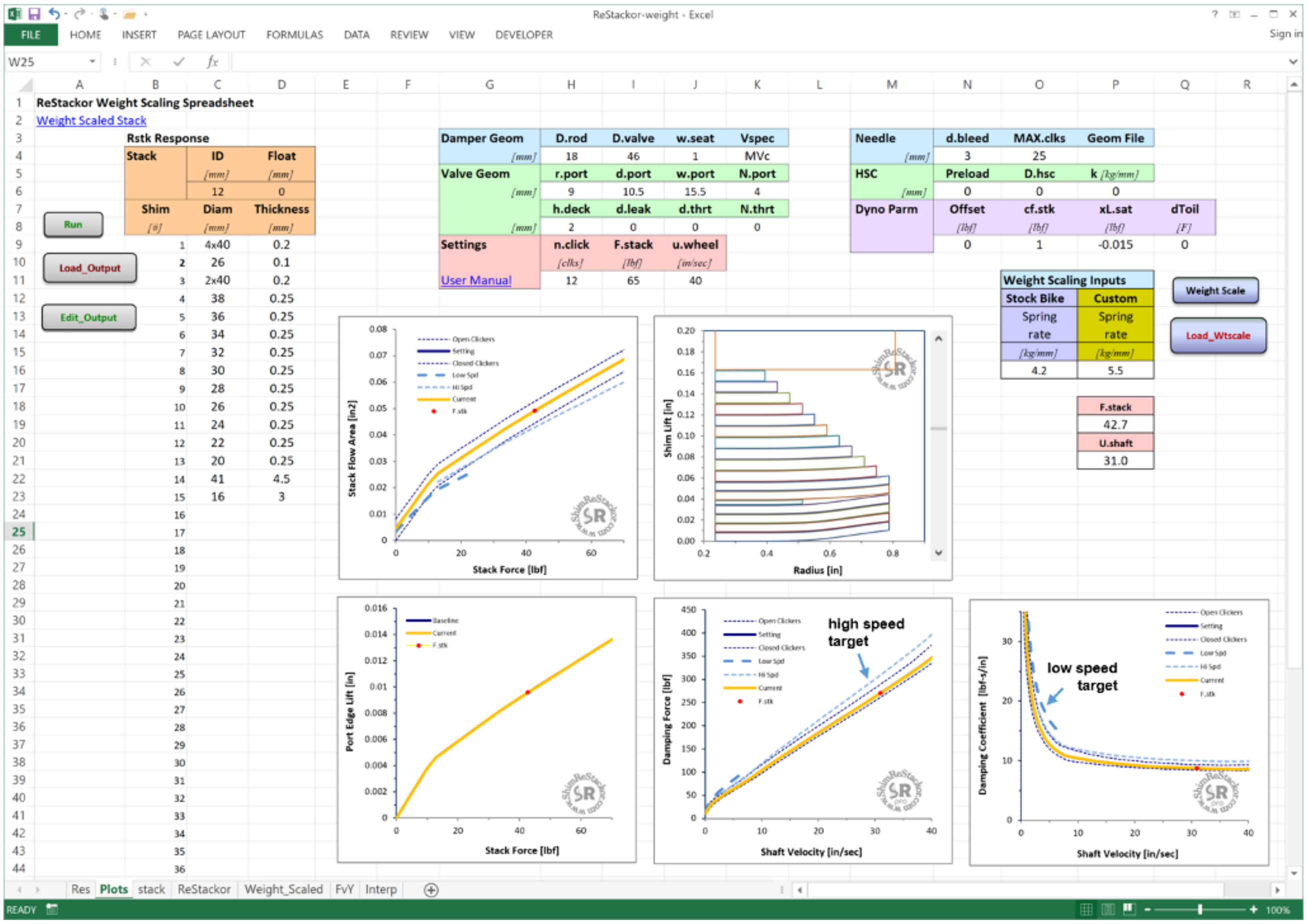
damping (zeta) $\zeta = \sqrt{2{,}450\,\frac{c_{shock}^2}{m\,k_{spring}}}$

c_{shock}	damping coefficient	kg_f-s/mm
k_{spring}	spring rate	kg_f/mm
m	wheel or chassis mass	kg
$y(t)$	wheel or chassis position	mm
t	time	sec
Imp	bump impulse	mm/sec

Weight scaling spreadsheet

The ReStackor-weight.xls spreadsheet makes weight scaling easy. There are three steps:

1. Enter the stock shim stack and valve port geometry to compute the stock damping performance
2. Enter the stock spring rate and the custom spring rate to scale to
    - Hit the “Weight Scale” and “Load_Wtscale” buttons
3. Hack the shim stack configuration to match the dashed blue line target weight scaled damping force



ReStackor Weight Scaling Spreadsheet

Weight Scaled Stack

Rstk Response

Stack	ID [mm]	Float [mm]
	12	0
Shim [#]	**Diam** [mm]	**Thickness** [mm]
1	4x40	0.2
2	26	0.1
3	2x40	0.2
4	38	0.25
5	36	0.25
6	34	0.25
7	32	0.25
8	30	0.25
9	28	0.25
10	26	0.25
11	24	0.25
12	22	0.25
13	20	0.25
14	41	4.5
15	16	3
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		
32		
33		
34		
35		
36		

Damper Geom	D.rod	D.valve	w.seat	Vspec
[mm]	18	46	1	MVc
Valve Geom	r.port	d.port	w.port	N.port
[mm]	9	10.5	15.5	4
	h.deck	d.leak	d.thrt	N.thrt
[mm]	2	0	0	0
Settings	n.click [clks]	F.stack [lbf]	u.wheel [in/sec]	
User Manual	12	65	40	

Needle	d.bleed	MAX.clks	Geom File	
[mm]	3	25		
HSC	Preload	D.hsc	k [kg/mm]	
[mm]	0	0	0	
Dyno Parm	Offset [lbf]	cf.stk [lbf]	xL.sat [lbf]	dToil [F]
	0	1	-0.015	0

Weight Scaling Inputs	
Stock Bike	Custom
Spring rate [kg/mm]	Spring rate [kg/mm]
4.2	5.5

F.stack
42.7
U.shaft
31.0

Correcting damping for changes in spring rate simply requires hacking around on the shim stack configuration to hit the target damping force curve.

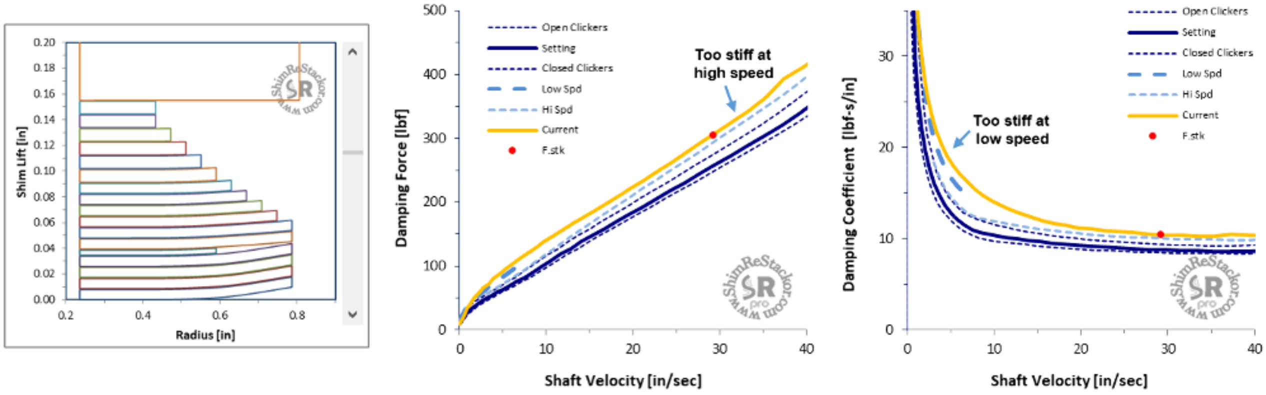
There are two targets. The bold dashed line sets low speed damping controlling chassis motions for the combined rider plus chassis weight.

The dotted blue line controls high speed wheel motions. Since the wheel weight is the same, the only correction needed is for the change in spring rate.

To hit the damping targets the example below uses a larger crossover diameter, a softer high speed stack and a stiffer clamp. The combination of those three changes to the shim stack gets low speed damping in the ball park, but high speed damping is too stiff.

Hitting both the low speed and high speed damping targets requires removing a face shim or a slightly smaller crossover shim diameter.

Add or remove shims to hit weight scaled target damping (light blue lines)

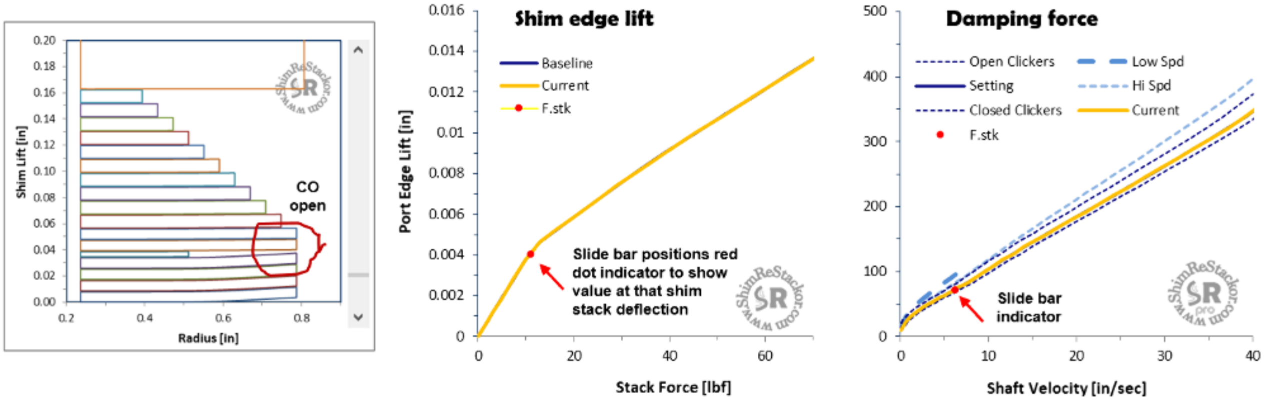


Shim stack slide bar

The weight scaling spreadsheet includes a slide bar on the shim stack graphic. Dragging the slide bar pans the shim stack through the deflection range and positions red dots on each plot indicating the value at that shim stack deflection.

The slide bar is useful to determine the relationship between shim stack deflection and damping force, the closure of crossover gaps and the shock shaft velocity where those event occur.

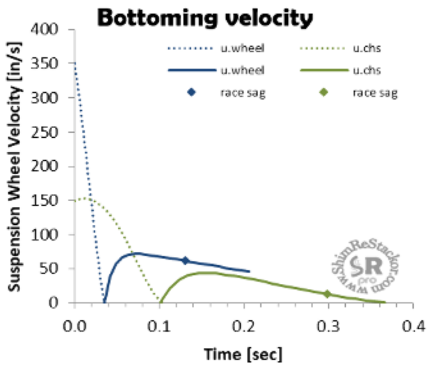
Shim stack slide bar shows connection between stack edge lift and damping force

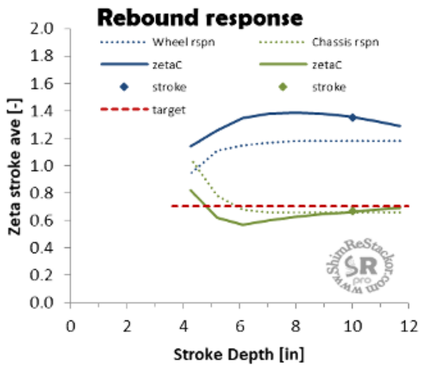


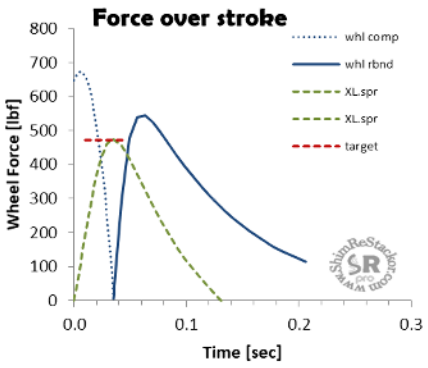
Suspension Response

Mid-valve spreadsheet

- Jump landing bottoming velocity
- Wheel bump bottoming velocity
- Rebound response
- Balance damping and spring force





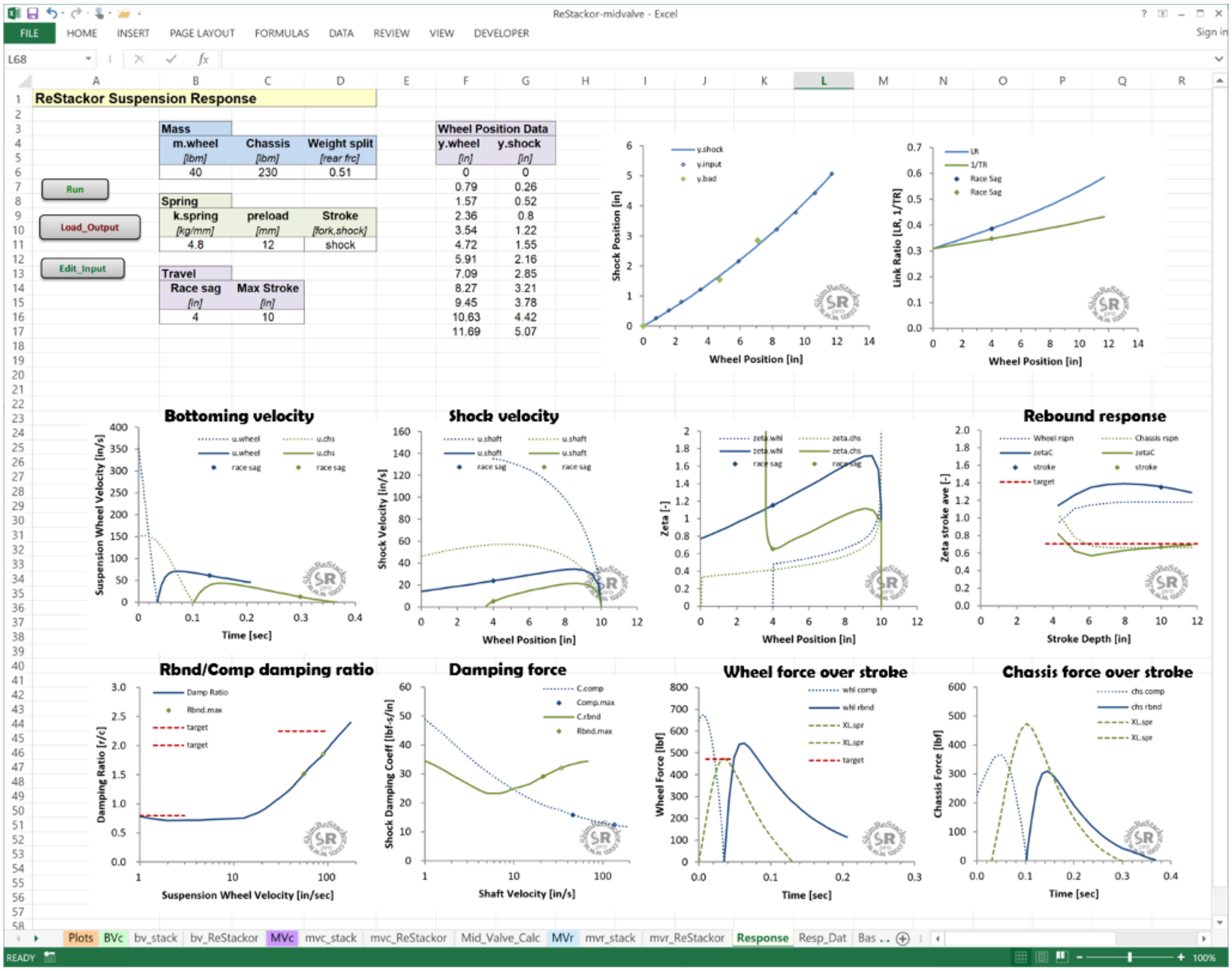


Suspension Response

The suspension response add-on to Shim ReStackor computes bottoming velocities on jump landings, bump impacts that bottoms the wheels, rebound response for nonlinear linked suspension systems and the instantaneous compression, rebound and spring force as the suspension moves through the stroke.

Those features translate the abstract concept of damping to a sense of suspension "feel".

- Test various combinations of spring rate and damping to control jump landing bottoming
- Test digressive damping force curves to reduce damping force at high speed and chassis deflection
- Modify rebound damping curve shapes to maintain consistent response across the range of suspension stroke depths



ReStackor Suspension Response

Mass		
m.wheel [lbm]	Chassis [lbm]	Weight split [rear frc]
40	230	0.51

Spring		
k.spring [kg/mm]	preload [mm]	Stroke [fork,shock]
4.8	12	shock

Travel	
Race sag [in]	Max Stroke [in]
4	10

Wheel Position Data	
y.wheel [in]	y.shock [in]
0	0
0.79	0.26
1.57	0.52
2.36	0.8
3.54	1.22
4.72	1.55
5.91	2.16
7.09	2.85
8.27	3.21
9.45	3.78
10.63	4.42
11.69	5.07

Figure 4: Response calculations quantify suspension bottoming velocities, rebound response and the strength of compression damping relative to spring force

Suspension response inputs

Damping: The Shim ReStackor mid-valve spreadsheet computes compression and rebound damping force. Response calculations access that data to determine jump landing bottoming velocities and suspension response.

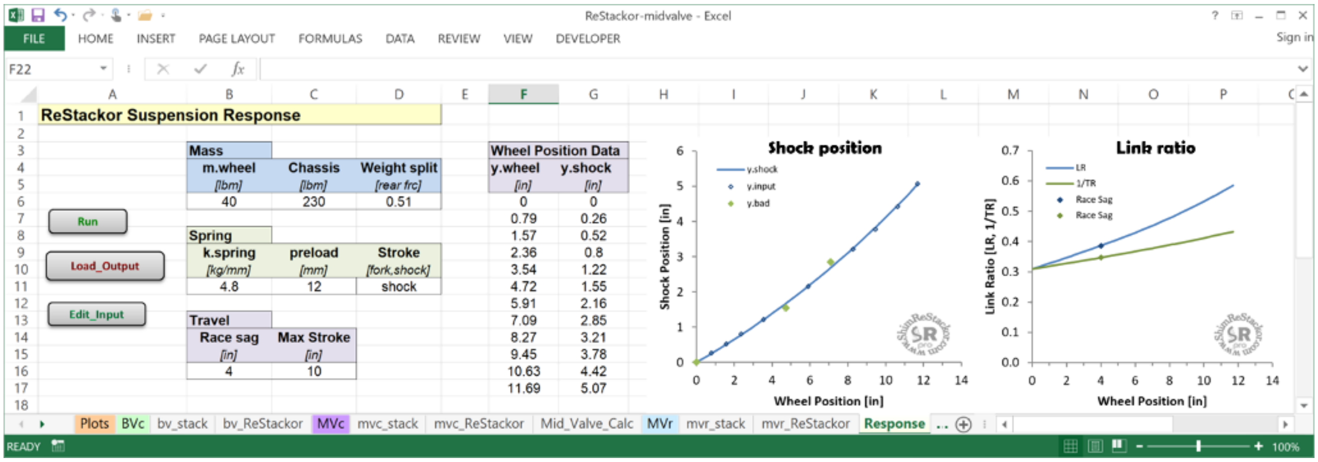
Mass: Inputs of un-sprung wheel weight, bike curb weight and the fraction of weight on the rear wheel specify the bike weight distribution.

Spring: The input spring rate coupled with Shim ReStackor inputs for the reservoir gas bladder pressure, ICS and fork oil level specify the spring force. Spring preload the Race sag inputs specify the rider weight.

Travel: The input race sag value specifies the rider weight and the ride height where bump motions start. Max Stroke specifies the stroke depth to be evaluated and must be greater than Race sag.

Link ratio

Shim ReStackor computes link ratio from inputs of wheel and shock shaft position. Up to 39 entries can be used. Inputs that deviate from the average curve are marked as "bad" with green data points. Measurements at the "bad" points should be double checked to insure accuracy of the link ratio curve.



ReStackor Suspension Response

Mass

m.wheel [lbm]	Chassis [lbm]	Weight split [rear frc]
40	230	0.51

Spring

k.spring [kg/mm]	preload [mm]	Stroke [fork,shock]
4.8	12	shock

Travel

Race sag [in]	Max Stroke [in]
4	10

Wheel Position Data

y.wheel [in]	y.shock [in]
0	0
0.79	0.26
1.57	0.52
2.36	0.8
3.54	1.22
4.72	1.55
5.91	2.16
7.09	2.85
8.27	3.21
9.45	3.78
10.63	4.42
11.69	5.07

Figure 5: Simple inputs - Thorough analysis - Practical results

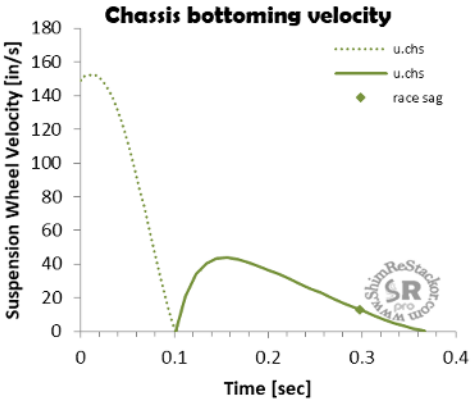
Jump landing bottoming

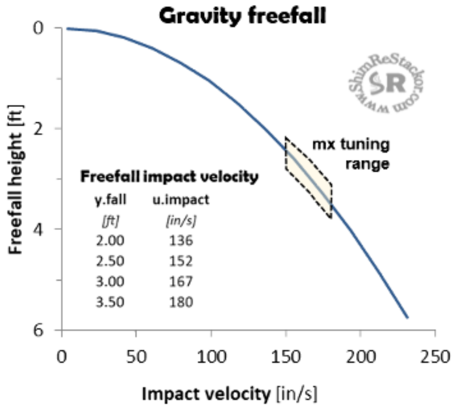
Response calculations use the input spring rate and computed compression damping force to determine the jump landing impact velocity that drives the suspension to the input "Max Stroke" depth. For the example shown an impact velocity of 150 in/sec is needed to drive the suspension into an eleven inch stroke depth.

Gravity dictates jump landing impact velocities. A 2.5 foot jump freefall produces an impact velocity of 152 in/sec. Jump heights that bottom the suspension can be increased or decreased by changing the spring rate or configuration of the compression damping shim stacks.

From the "Max Stroke" position at 0.1 seconds the response calculations continue into the rebound stroke. The dot symbol on the rebound curve indicates the time required to return to race sag. The residual stroke velocity on race sag return indicates the suspension will overshoot race sag and baby-buggy back through a low speed compression stroke.

Rebound stroke response calculations stop when the suspension reaches zero velocity or full suspension extension.





Freefall impact velocity

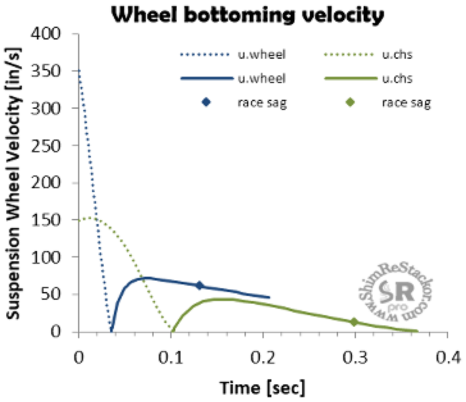
$$y = \frac{u^2}{9{,}274}$$

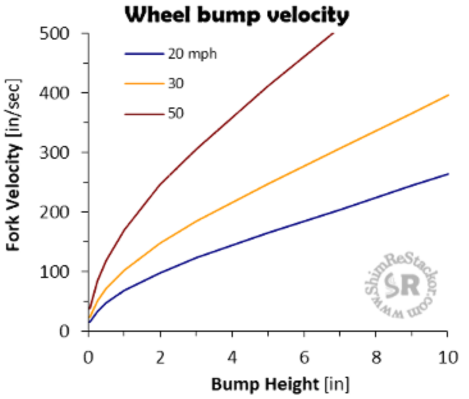
$$y[ft];\;\; u\left[\frac{in}{sec}\right]$$

Wheel bottoming velocity

Response calculations also compute the bump velocity required to drive the wheels to the input "Max Stroke" depth. For the example, a bump impact velocity of 350 in/sec is required approximately equivalent to hitting an 8.5 inch square edge step at 30 mph.

Enduro setups emphasizing bump compliance to reduced chassis deflection off root and rock impacts require softer compression damping and the softer damping produces a lower wheel bottoming velocity.





Rebound response

Linked suspension systems produce a progressive increase in shock shaft motion as the suspension is driven deeper into the stroke. The progressive link ratio makes the spring force progressive and has an even larger effect on increasing damping force.

Response calculations compute the instantaneous suspension response zeta value showing how the change in link ratio over the stroke effects damping performance.

For suspension tuning purposes, the instantaneous response values need to be integrated over the stroke to determine the stroke averaged response and suspension performance. Shim ReStackor response calculations perform that integration starting with short strokes around race sag and advancing to progressively deeper strokes to determine the stroke averaged response coefficient at each stroke depth.

The rebound response target for performance suspension systems produces a rebound response zeta value of 0.7. Response calculations mark that target.

The example below demonstrates a typical suspension tuning problem. The rider has closed down the clickers to get good rebound response for small strokes around race sag. But, when the suspension is pushed deeper in the stroke the suspension goes underdamped.

To fix the problem the rebound shim stack needs a larger crossover diameter or a stiffer high speed stack to produce a consistent suspension response zeta value of 0.7 over the range of suspension stroke depths.

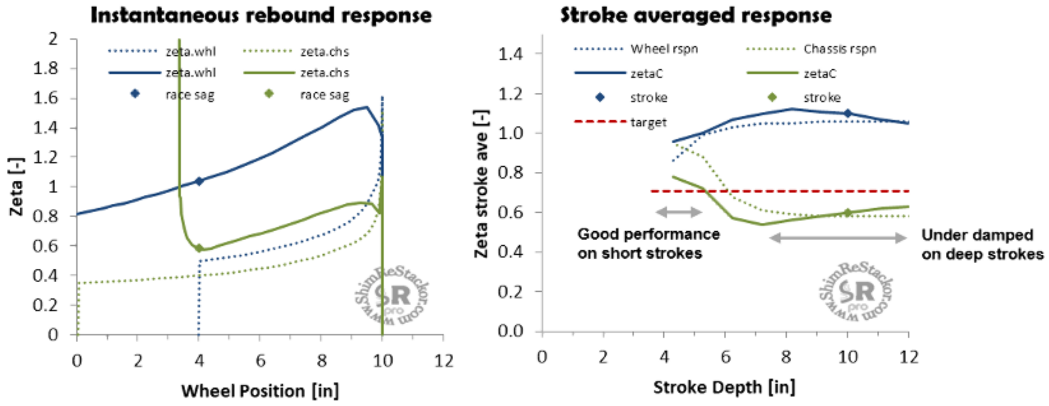


Figure 6: Stroke averaged response shows how the suspension response varies over the suspension stroke depth range

Damping ratio

Damping ratio, the ratio of rebound to compression damping, is often used as a general rule of thumb to quantify shock absorber performance. The typical value is 2:1.

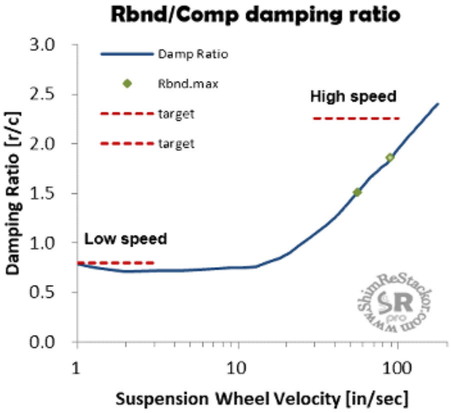
Shocks with damping ratios below 2:1 have stiff compression damping to provide bottoming resistance. Damping ratios above 2:1 have light compression damping setup to improve compliance on root and rock impacts.

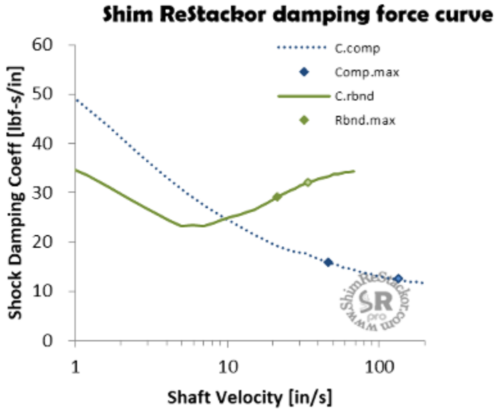
Low speed target

Rebound damping at the target zeta value of 0.7 is underdamped. Underdamped means the rebound stroke will overshoot race sag and baby-buggy back. Baby-buggy motions give poor suspension “feel”. Tuners have a trick to prevent the baby-buggy motion.

At low speed, below suspension speeds of 6 in/sec, the ratio of rebound to compression damping needs to be in the range of 0.8:1. That ratio sets low speed compression damping stiffer than rebound.

Stiff low speed compression damping catches the rebound overshoot, holds the suspension “high in the stroke” and heavily damps the overshoot return stroke to prevent baby-buggy motions.





Force over stroke

The highest suspension velocities occur at bump impact. As the suspension slows the compression damping force drops off while the spring force ramps up. At the "Max Stroke" position the suspension stops and reverses into the rebound stroke.

Spring force, on the force over stroke plots, is the sum of main spring plus the gas spring force set by the fork oil level or shock gas reservoir pressure. The spring force is set to zero at race sag since there is no force causing suspension motion at race sag.

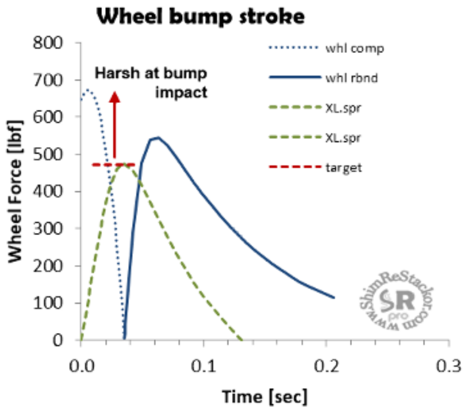
The force over stroke plot gives some insight into suspension "feel" and harshness. For the example shown the wheel spring force at bottoming is approximately 450 lbf. The compression damping force at bump impact is near 700 lbf, making the force at bump impact 250 lbf greater than the peak spring force.

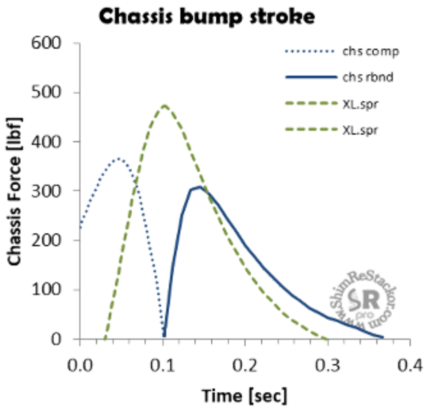
Compression damping makes the suspension stiff at bump impact and then blows through to the softer spring force at bottoming. Stiff compression damping at bump impact makes the suspension harsh.

To fix that a more digressive compression damping curve is needed to produce a lower compression damping force at bump impact while maintaining the stiff compression damping needed to prevent bottoming on jump landings.

An alternative is run a stiffer spring to prevent bottoming with lighter compression damping.

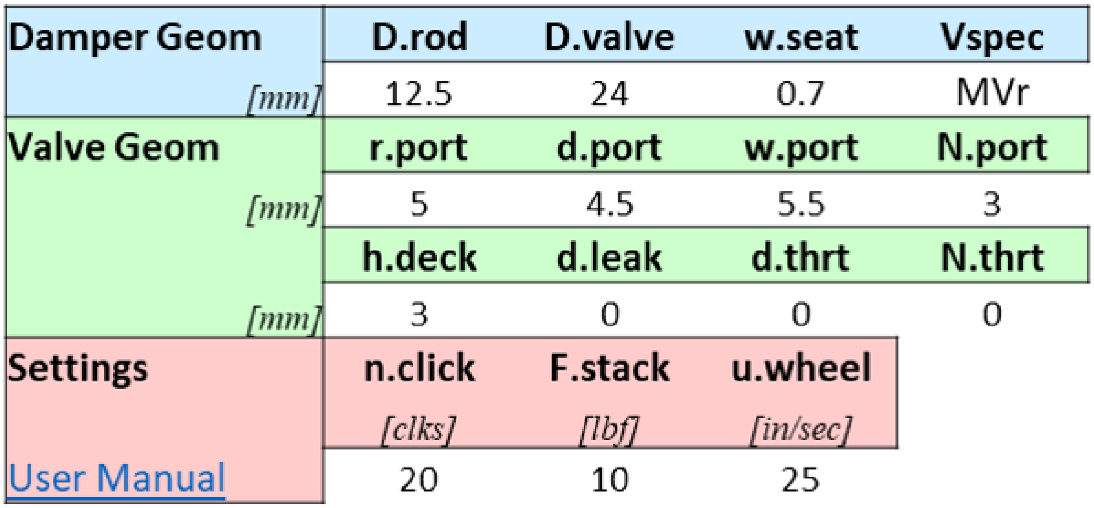
Further discussion of rebound and compression damping tuning strategies are given on the ReStackor web site.





Calculation Inputs

- Shim stack configuration
- Valve port geometry
- Clicker needle geometry
- Reservoir pressurization systems

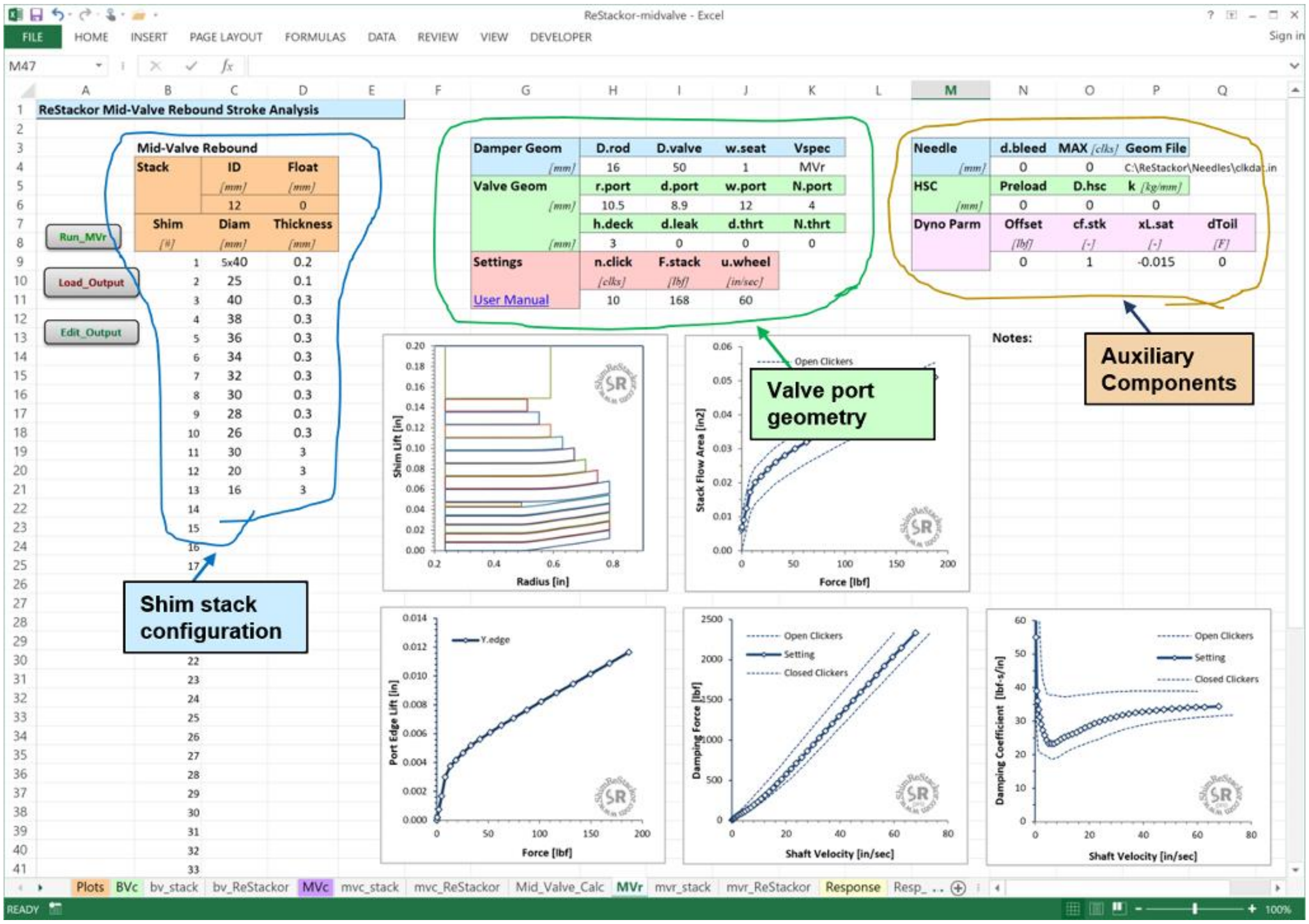


Damper Geom	**D.rod**	**D.valve**	**w.seat**	**Vspec**
[mm]	12.5	24	0.7	MVr
Valve Geom	**r.port**	**d.port**	**w.port**	**N.port**
[mm]	5	4.5	5.5	3
	h.deck	**d.leak**	**d.thrt**	**N.thrt**
[mm]	3	0	0	0
Settings	**n.click**	**F.stack**	**u.wheel**	
	[clks]	*[lbf]*	*[in/sec]*	
User Manual	20	10	25	

Calculation inputs

There are three sections to the Shim ReStackor spreadsheet inputs with additional inputs on the "Plots" tab specifying the oil reservoir pressurization system:

1) Shim stack configuration
2) Valve port geometry
3) Auxiliary components:
    - Clicker bleed
    - Compression adjuster spring
    - Dyno test parameters



ReStackor Mid-Valve Rebound Stroke Analysis

Mid-Valve Rebound

Stack	**ID** *[mm]*	**Float** *[mm]*
	12	0

Shim *[#]*	**Diam** *[mm]*	**Thickness** *[mm]*
1	5x40	0.2
2	25	0.1
3	40	0.3
4	38	0.3
5	36	0.3
6	34	0.3
7	32	0.3
8	30	0.3
9	28	0.3
10	26	0.3
11	30	3
12	20	3
13	16	3
14		
15		
16		
17		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		
32		
33		

Damper Geom	**D.rod**	**D.valve**	**w.seat**	**Vspec**
[mm]	16	50	1	MVr
Valve Geom	**r.port**	**d.port**	**w.port**	**N.port**
[mm]	10.5	8.9	12	4
	h.deck	**d.leak**	**d.thrt**	**N.thrt**
[mm]	3	0	0	0
Settings	**n.click**	**F.stack**	**u.wheel**	
	[clks]	*[lbf]*	*[in/sec]*	
User Manual	10	168	60	

Needle	**d.bleed**	**MAX** *[clks]*	**Geom File**	
[mm]	0	0	C:\ReStackor\Needles\clkdat.in	
HSC	**Preload**	**D.hsc**	**k** *[kg/mm]*	
[mm]	0	0	0	
Dyno Parm	**Offset**	**cf.stk**	**xL.sat**	**dToil**
	[lbf]	*[-]*	*[-]*	*[F]*
	0	1	-0.015	0

Shim stack configuration

A simple listing of shim diameter and thickness specifies the shim stack configuration. Shim #1 is on the valve face with a maximum input of 50 shims.

The final two entries in the shim stack listing must specify the shim stack clamp washer and nut dimensions. The calculations will fail if there is nothing backing the shim stack clamp.

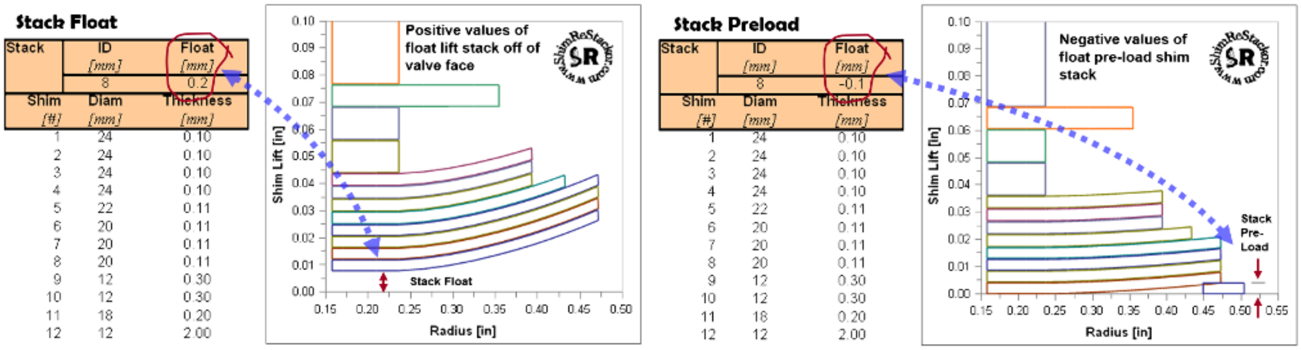
The shim stack deflection graphic produced by the calculation outputs helps to insure the shim stack configuration input matches the intended configuration. The graphic also identifies closure of crossover gaps and collision of face shims with the stack clamp washer which may prevent the shim stack from fully opening at high speed.

ID: The inside diameter of the shim in millimeters. All shims in the stack have the same inside diameter.

Float: The gap in millimeters between the valve face and shim stack face shim, typically zero

- Positive values of float allow the shim stack to lift off the valve face using the classic definition of float. The rate of float opening is controlled by the high speed compression (HSC) spring stiffness and the cracking pressure controlled by the HSC spring preload. The HSC configuration is specified in the auxiliary input block.
- Negative values of float preload the shim stack for modeling of a dished valve face or valves with an edge lip.

.



Stack Float

Stack	ID [mm]	Float [mm]
	8	0.2
Shim [#]	Diam [mm]	Thickness [mm]
1	24	0.10
2	24	0.10
3	24	0.10
4	24	0.10
5	22	0.11
6	20	0.11
7	20	0.11
8	20	0.11
9	12	0.30
10	12	0.30
11	18	0.20
12	12	2.00

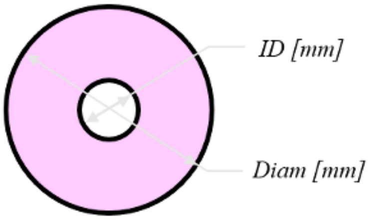
Stack Preload

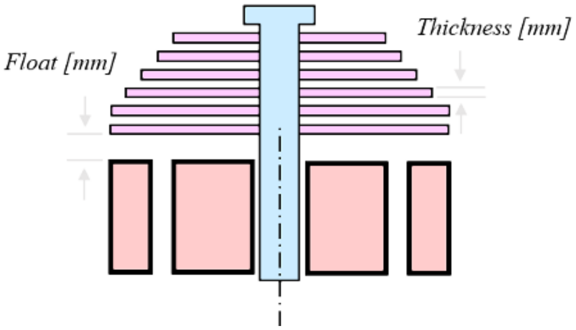
Stack	ID [mm]	Float [mm]
	8	-0.1
Shim [#]	Diam [mm]	Thickness [mm]
1	24	0.10
2	24	0.10
3	24	0.10
4	24	0.10
5	22	0.11
6	20	0.11
7	20	0.11
8	20	0.11
9	12	0.30
10	12	0.30
11	18	0.20
12	12	2.00

Figure 7: A simple listing of shim diameter and thickness specifies the shim stack configuration

Shim stack configuration

Stack	ID [mm]	Float [mm]
	6	0
Shim [#]	Diam [mm]	Thickness [mm]
1	2x22	0.30
2	21	0.20
3	20	0.20
4	19	0.20
5	18	0.20
6	9	3





- **Shim [#]:** Up to 50 shims can be input. If you only need 10 shims leave the rest of the cells blank
- **Diam:** Shim outside diameter in millimeters. Multiple shims of the same diameter and thickness can be input

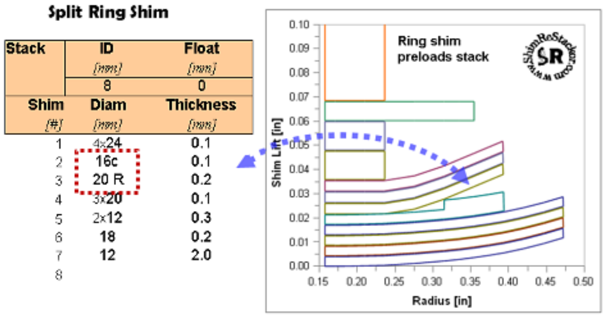
using a prefix nx40 or n*40 to indicate "n" shims of 40 mm diameter

- **Thickness:** Thickness of the shim in millimeters
- **Stack clamp and nut:** The final two entries in the shim stack listing must be the clamp washer diameter and thickness and the nut diameter clamping the shim stack

Ring Shims

Ring shims or split ring shims require two inputs:

- The first entry specifies the centering shim diameter and thickness. The center shim is marked by putting a "c" after the shim diameter
- The second entry specifies the outer ring shim diameter and thickness. The ring shim is marked by putting a "r" after the shim diameter. Upper or lower case letters can be used as shown in the example


Split Ring Shim

Stack	ID [mm]	Float [mm]
	8	0
Shim [#]	Diam [mm]	Thickness [mm]
1	4x24	0.1
2	16c	0.1
3	20 R	0.2
4	3x20	0.1
5	2x12	0.3
6	18	0.2
7	12	2.0
8		

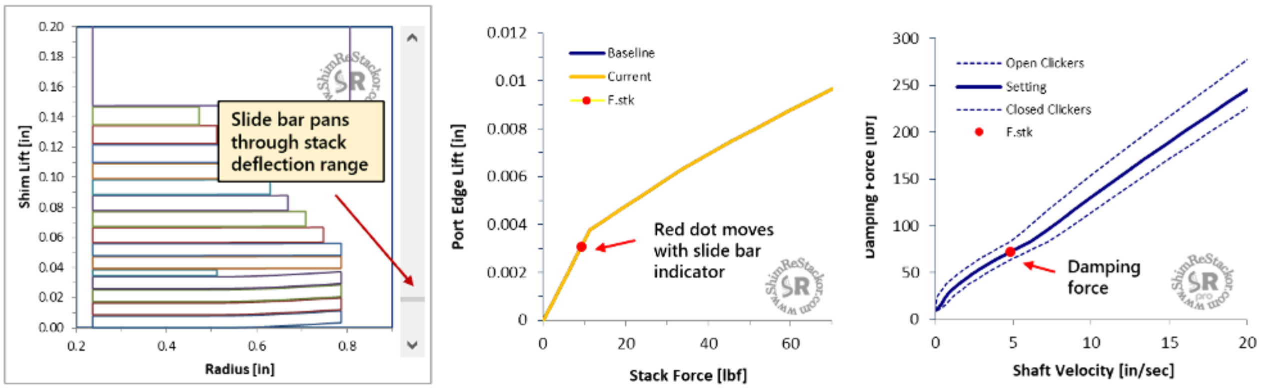
XXc [=] Centering shim diameter
XXr [=] Ring shim diameter

Shock shaft velocity and shim stack deflection

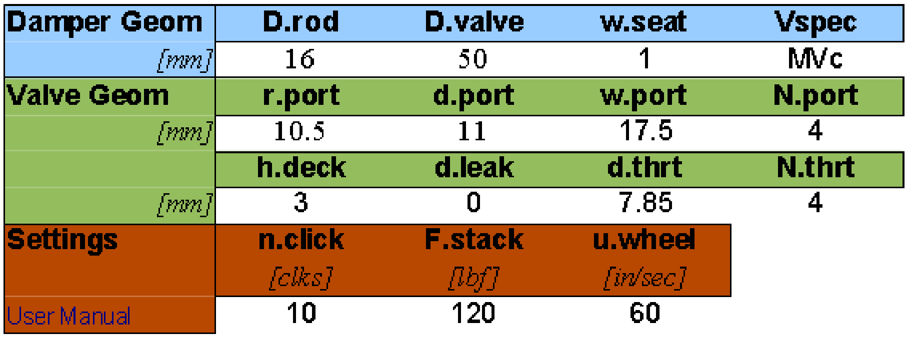
The Shim ReStackor weight scaling spreadsheet includes a slide bar on the shim stack deflection graphic. Panning the slide bar through the range deflects the shim stack and positions red dots on the damping force plots indicating the value at that slide bar position.

The weight scaling spreadsheet slide bar feature is useful to determine shaft velocities where crossover gaps close and the connection between shim stack deflection and damping force produced by the shock.

Slide bar on weight scaling spreadsheet shows connection between stack deflection and damping force



Valve Port Geometry



Damper Geom	D.rod	D.valve	w.seat	Vspec
[mm]	16	50	1	MVc
Valve Geom	r.port	d.port	w.port	N.port
[mm]	10.5	11	17.5	4
	h.deck	d.leak	d.thrt	N.thrt
[mm]	3	0	7.85	4
Settings	n.click	F.stack	u.wheel	
	[clks]	*[lbf]*	*[in/sec]*	
User Manual	10	120	60	

D.rod: The shock absorber shaft diameter in millimeters

D.valve: The shock absorber valve diameter. More specifically, D.valve specifies the inside diameter of the shock absorber body, millimeters

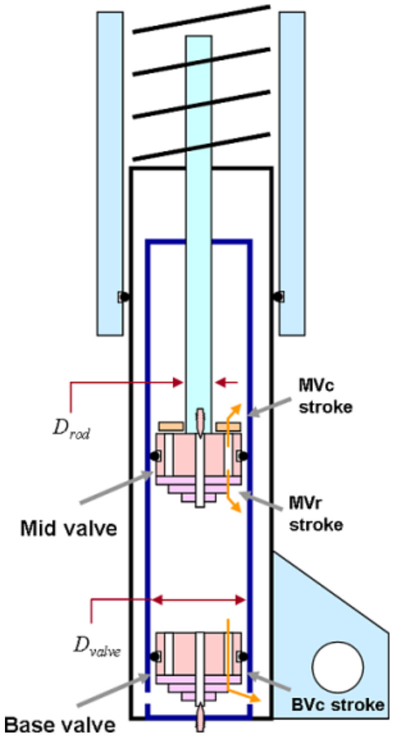
w.seat: The valve port seat width in millimeters

Vspec: Shock absorber stroke to be analyzed

- BVc: Base valve compression
- MVc: Mid-valve compression
- MVr: Mid-valve rebound

The Vspec input is also used to extract your User key, input the code authorization key and display the code version of the installed Shim ReStackor software

- **Ukey:** The pop-up execution window will show your User key
- **Ckey:** The pop-up execution window will prompt you to enter your Shim ReStackor code key purchased through PayPal
- **Ver:** The pop-up execution window will show the code version of the installed Shim ReStackor software



Suspension stroke (BVc, MVr, MVc)

There are two types of shock absorber valves: base valves and mid-valves.

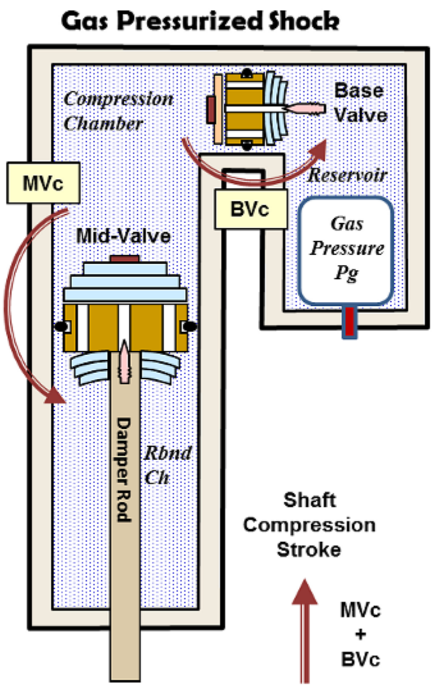
BVc Base valve compression adjuster

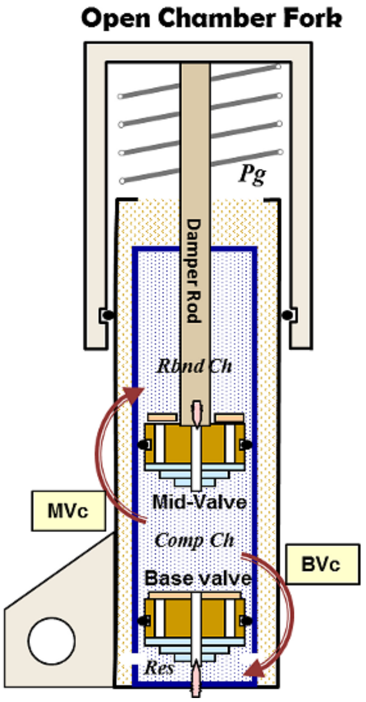
The base valve, or compression adjuster, is located on the opposite end of the shock from the damper rod entrance. As the damper rod is forced into the shock, an equal volume of fluid is forced out of the shock through the base valve into the fluid reservoir. Since the damper rod has a small diameter, the flow through the base valve is small. A base valve stroke is specified in ReStackor by setting the Vspec keyword to BVc.

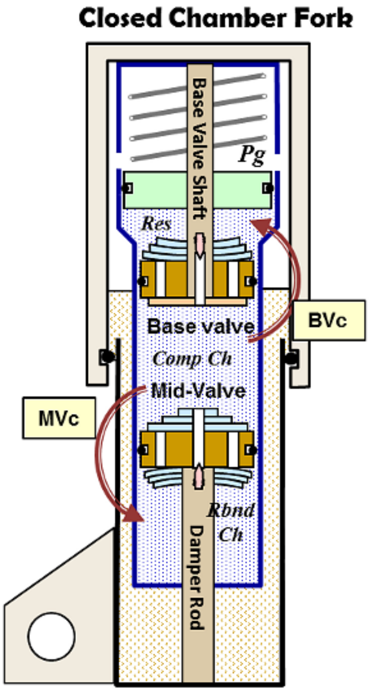
Mid-valve MVr and MVc

A mid-valve is located on the end of the damper rod. As the damper rod is forced into the shock fluid is forced through the mid valve to fill in the volume behind the valve. On the compression stroke, MVc, the entire face of the mid-valve is pressurized. On the rebound stroke, MVr, the annular area between the damper rod and valve OD is pressurized.

Setting the Vspec keyword to MVc (mid-valve compression), MVr (mid-valve rebound) or BVc (base valve compression) sets ReStackor to run the three different strokes of a shock absorber.


Gas Pressurized Shock


Open Chamber Fork


Closed Chamber Fork

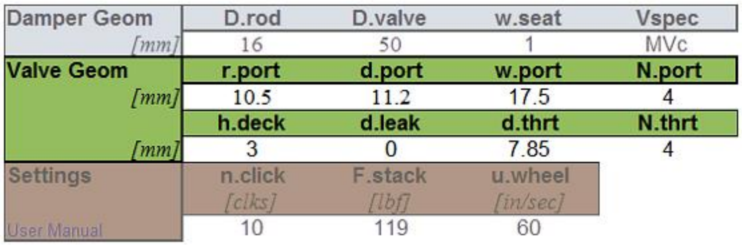
User key and code key purchase

The Vspec keyword is also used to extract your User key and input your code key purchased through the Shim ReStackor web site at PayPal.

To obtain your User key install the Shim ReStackor demo software and reset the Vspec keyword from (BVc, MVc or MVr) to “Ukey”. When the spreadsheet run button is hit the pop-up execution window will display your User key.

To input your code key purchased through PayPal set the Vspec keyword to “Ckey”. When the run button is hit the pop-up execution window will prompt you to input your code key.

Valve Port Geometry



Damper Geom	D.rod	D.valve	w.seat	Vspec
[mm]	16	50	1	MVc
Valve Geom	r.port	d.port	w.port	N.port
[mm]	10.5	11.2	17.5	4
	h.deck	d.leak	d.thrt	N.thrt
[mm]	3	0	7.85	4
Settings	n.click	F.stack	u.wheel	
	[clks]	[lbf]	[in/sec]	
User Manual	10	119	60	

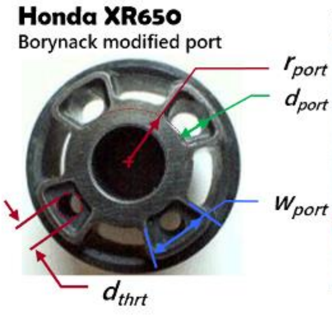
r.port: The radial distance from the valve center to the port inside edge in millimeters. R.port defines the inner radius of the shim stack face pressurized by the valve port.

w.port: The valve port width at the outside edge in millimeters. W.port defines the valve port seat length metering outward radial spill. Also see the w.port definition below for a compression adjuster with a continuous perimeter seat.

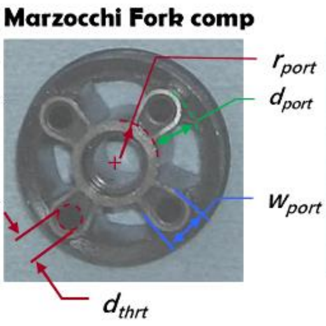
d.port: The radial length of the valve port side in millimeters. D.port defines the valve port seat length controlling sideways tangential spill out of the valve port

The sum of r.port plus d.port must be less than or equal to half of the valve diameter. Otherwise, the code will kick out with an error message.

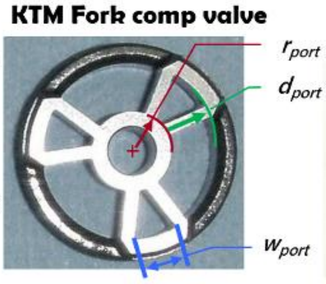
N.port: The number of valve ports. The Honda and Marzocchi valves shown below have four ports. The KTM valve has three ports.



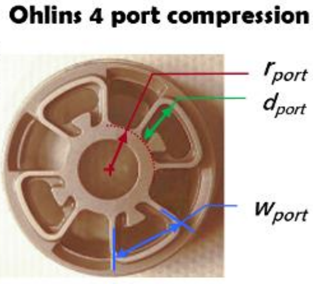
Honda XR650
Borynack modified port



Marzocchi Fork comp

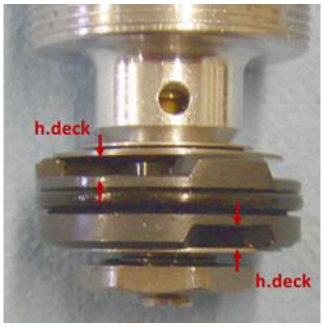


KTM Fork comp valve



Ohlins 4 port compression

h.deck: Port entrance deck height in millimeters. The deck height between the reverse flow shim stack and valve face creates a flow restriction at the valve port entrance. ReStackor uses h.deck*w.port to define the available flow area. Installing delta shims on the reverse flow shim stack raise the deck height and reduces the port entrance flow loss.



d.leak: Valve port leak jet diameter in millimeters. For valves with a single leak jet on a single port the value of d.leak is simply the jet diameter. For valves with multiple leak jets on one port the "effective" jet diameter is [d.leak= sqrt(N.jets) d.jet] where N.jets is the number of leak jets. For valves with leak jets on multiple ports the input is "Nport x Deff" where Nport specifies the number of ports with a leak jet and D.eff defines the leak jet diameter on a single port.

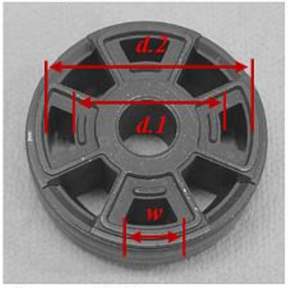
- "1.5" specifies a single leak jet on one valve port with a 1.5 mm diameter
- "3x0.5" specifies a 0.5 mm leak jet installed on three of the valve ports

d.thrt: The effective flow diameter of the valve port throat. Free flowing valves, like the KTM valve above, d.port and w.port define the valve port flow area and there is no restriction. For free flowing valves both D.thrt and N.thrt are set to zero.

For valves with port restrictions, like the Honda and Marzocchi valves above, D.thrt defines the valve port throat minimum flow area. Example calculations to determine d.thrt for trapezoid and parabolic shaped port restrictions are shown below.

N.thrt: The number of valve port throat restrictions. For the Honda and Marzocchi valves above each port has one throat restriction so N.port and N.thrt have the same value of four. In general, N.thrt and N.port are equal. However, ReStackor allows for the special case where multiple valve side ports feed a single valve port, in that case N.thrt > N.port.

Trapezoid Throat



Trapezoid Throat

$$A_{thrt} \cong \frac{\pi}{4}\left(d_2^2 - d_1^2\right)\frac{w}{\pi d_2}$$

$$d_{thrt} = \sqrt{\frac{4}{\pi}A_{thrt}}$$

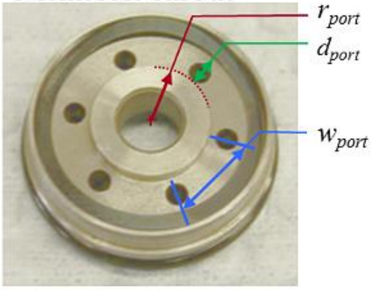
Parabolic Throat

Parabolic Throat

$$A_{thrt} = \frac{\pi}{4}h^2 + h(w-h)$$

$$d_{thrt} = \sqrt{\frac{4}{\pi}A_{thrt}}$$

Perimeter Throat



Perimeter Port

$$w_{port} = 2\left(r_{port} + d_{port}\right)\sin\left(\frac{\pi}{n_{port}}\right) \text{ radians}$$

$$w_{port} = 2\left(r_{port} + d_{port}\right)\sin\left(\frac{180}{n_{port}}\right) \text{ degrees}$$

The parameters d.port, w.port and N.port define the valve port flow area. The additional parameters N.thrt and D.thrt handle the special case where a restriction in the valve port reduces the flow area. The parameters N.thrt and D.thrt also allow modeling of the special case where multiple side ports feed a single valve port.

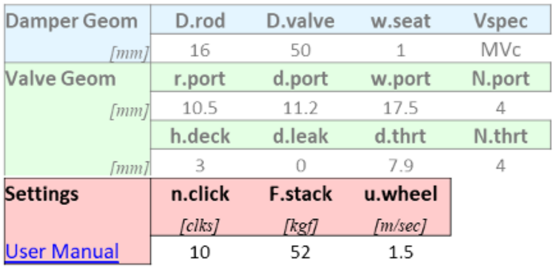
Settings

The settings input block defines the clicker position, fluid force applied to the shim stack face and the maximum shock absorber shaft velocity to be computed.

n.click: The clicker setting. n.click specifies the number of clicks out from full closed.

F.stack: Maximum fluid force applied to the shim stack face. Shim ReStackor calculations compute the stack structure deflection, stack edge lift and flow area up to the maximum value specified by F.stack in [lbf].

u.wheel: The maximum shock absorber shaft velocity in inches per second. ReStackor computes the damping force as a function of suspension velocity up to the value specified by u.wheel. If the fluid force on the shim stack is greater than the value specified by F.stack the calculations internally iterate to determine the fluid force acting on the shim stack consistent with the requested u.wheel shock shaft velocity. However, the shim stack deflection plot is drawn at the value specified by F.stack.

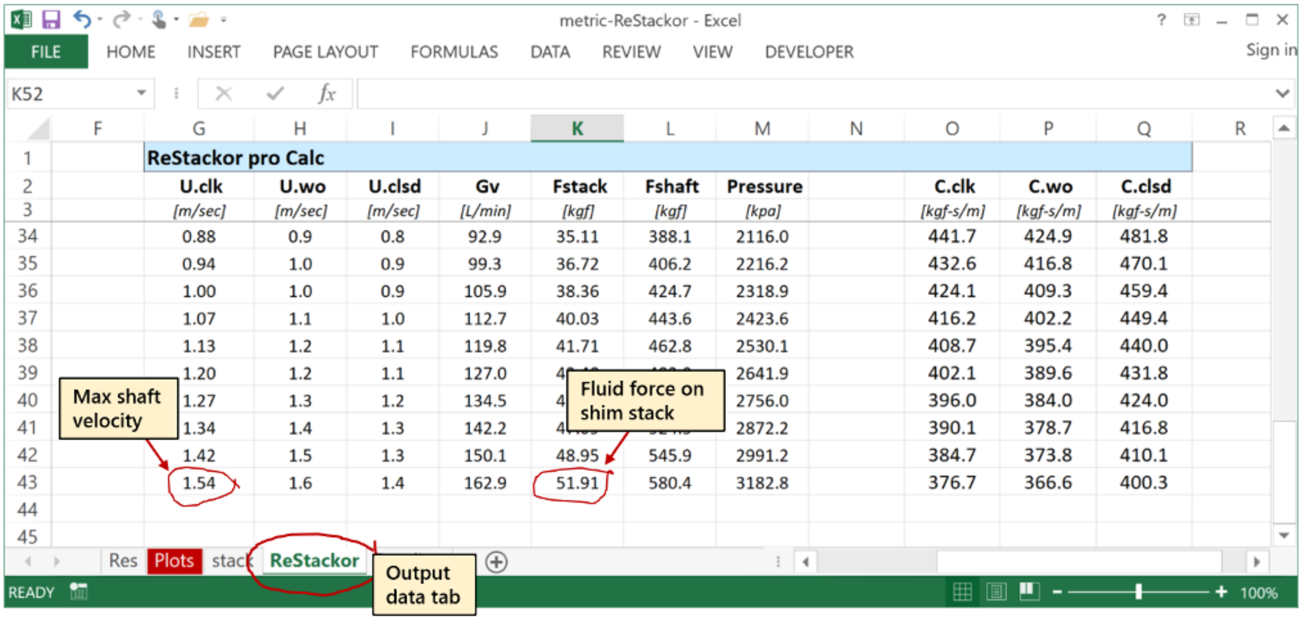


Damper Geom	D.rod	D.valve	w.seat	Vspec
[mm]	16	50	1	MVc
Valve Geom	r.port	d.port	w.port	N.port
[mm]	10.5	11.2	17.5	4
	h.deck	d.leak	d.thrt	N.thrt
[mm]	3	0	7.9	4
Settings	n.click	F.stack	u.wheel	
	[clks]	[kgf]	[m/sec]	
User Manual	10	52	1.5	

Separate inputs for F.stack and u.wheel allow the stack structure to be displayed at a low applied force, like examining where a crossover gap closes, while the damping force is computed over a larger shaft velocity range.

For efficient calculations, the input value of F.stack should match the computed F.stack value shown in the calculation outputs at the maximum shock shaft velocity. Matching F.stack avoids internal calculation iterations and gives faster calculation results.

Calculations are more efficient if shim stack fluid force "guess" matches maximum shaft velocity



ReStackor pro Calc

	F	G	H	I	J	K	L	M	N	O	P	Q
2		U.clk	U.wo	U.clsd	Gv	Fstack	Fshaft	Pressure		C.clk	C.wo	C.clsd
3		[m/sec]	[m/sec]	[m/sec]	[L/min]	[kgf]	[kgf]	[kpa]		[kgf-s/m]	[kgf-s/m]	[kgf-s/m]
34		0.88	0.9	0.8	92.9	35.11	388.1	2116.0		441.7	424.9	481.8
35		0.94	1.0	0.9	99.3	36.72	406.2	2216.2		432.6	416.8	470.1
36		1.00	1.0	0.9	105.9	38.36	424.7	2318.9		424.1	409.3	459.4
37		1.07	1.1	1.0	112.7	40.03	443.6	2423.6		416.2	402.2	449.4
38		1.13	1.2	1.1	119.8	41.71	462.8	2530.1		408.7	395.4	440.0
39		1.20	1.2	1.1	127.0	[illegible]	[illegible]	2641.9		402.1	389.6	431.8
40		1.27	1.3	1.2	134.5	[illegible]	[illegible]	2756.0		396.0	384.0	424.0
41		1.34	1.4	1.3	142.2	[illegible]	[illegible]	2872.2		390.1	378.7	416.8
42		1.42	1.5	1.3	150.1	48.95	545.9	2991.2		384.7	373.8	410.1
43		1.54	1.6	1.4	162.9	51.91	580.4	3182.8		376.7	366.6	400.3
44												
45												

Auxiliary components

Needle geometry

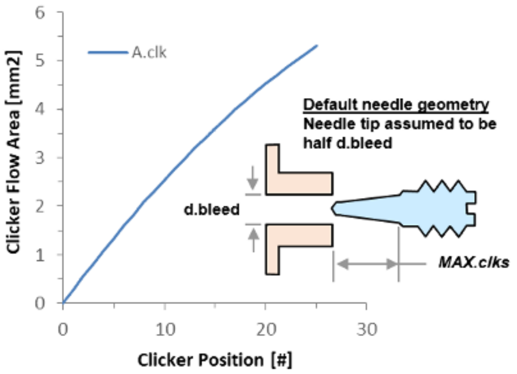
The default needle geometry is a simple tapered cone with a tip diameter equal to half of the needle seat diameter. d.bleed defines the needle seat diameter. MAX.clks defines the number of clicks from closed to wide open.

d.bleed: Bleed port diameter at the needle seat in [mm].

MAX.clks: The number of adjuster clicks from closed to full open with the needle tip positioned flush with the seat.

Default needle geometry inputs

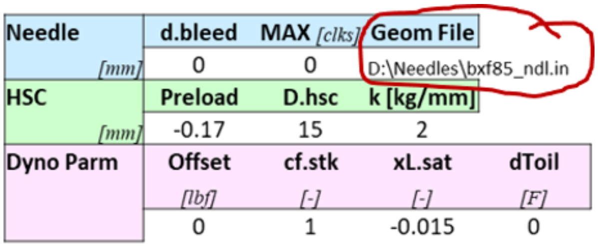
Needle	d.bleed	MAX *[clks]*	Geom File	
[mm]	3	25		
HSC	Preload	D.hsc	k [kg/mm]	
[mm]	-0.17	15	2	
Dyno Parm	Offset	cf.stk	xL.sat	dToil
	[lbf]	*[-]*	*[-]*	*[F]*
	0	1	-0.015	0



Needle geometry file

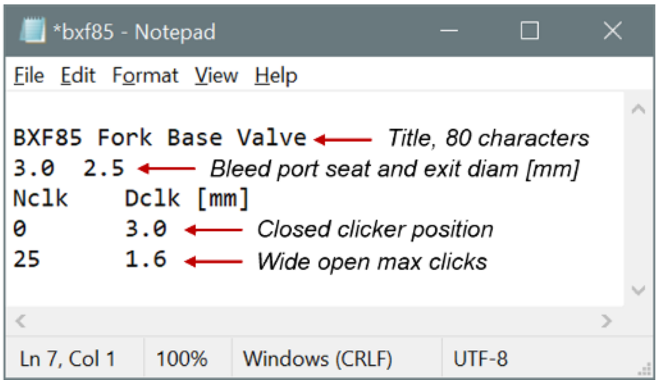
Alternatively, a needle “Geom File” can be used to specify the needle diameter as a function of clicker position. Virtually any needle geometry can be described in the table with up to 100 entries giving a precise description of the bleed circuit flow area and low speed damping force.

Geom File: Setting both d.bleed and MAX.clks to zero triggers the calculations look for a needle geometry table at the file path specified by Geom.File. In the example the needle geometry table is located at D:\Needles\bxf85_ndl.in.



Needle	d.bleed	MAX *[clks]*	Geom File	
[mm]	0	0	D:\Needles\bxf85_ndl.in	
HSC	Preload	D.hsc	k [kg/mm]	
[mm]	-0.17	15	2	
Dyno Parm	Offset	cf.stk	xL.sat	dToil
	[lbf]	*[-]*	*[-]*	*[F]*
	0	1	-0.015	0

Clicker needle geometry input table



```
BXF85 Fork Base Valve
3.0  2.5
Nclk    Dclk [mm]
0       3.0
25      1.6
```

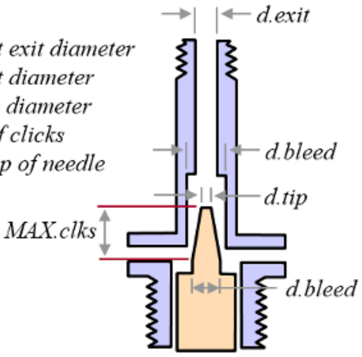
Title, 80 characters

Bleed port seat and exit diam [mm]

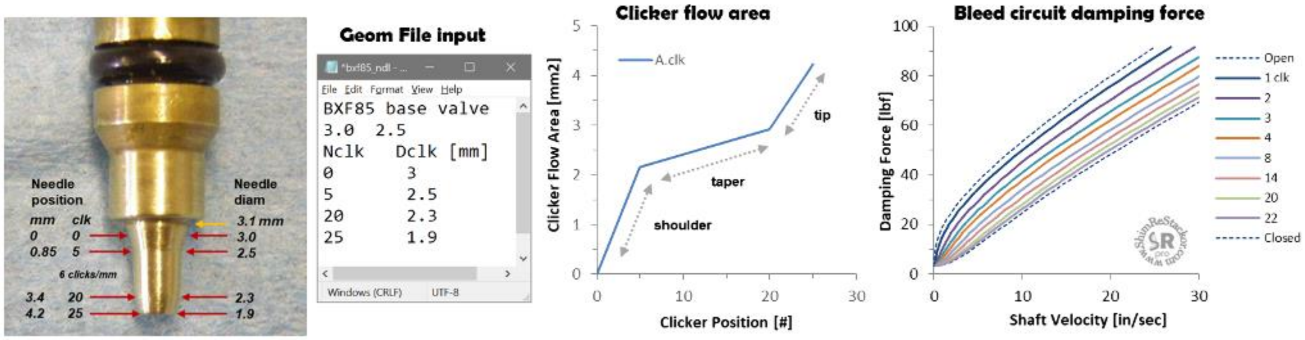
Closed clicker position

Wide open max clicks

d.exit	*[=] Bleed port exit diameter*
d.bleed	*[=] Bleed port diameter*
d.tip	*[=] Needle tip diameter*
MAX.clks	*[=] Number of clicks from base to tip of needle*



Clicker needle table inputs describe virtually any needle geometry



```
BXF85 base valve
3.0  2.5
Nclk   Dclk [mm]
0      3
5      2.5
20     2.3
25     1.9
```

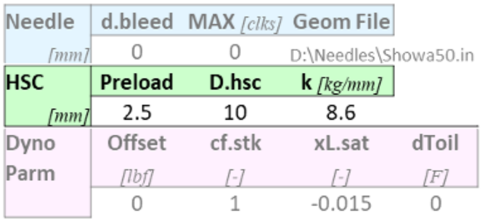
High speed compression adjuster and Mid-valve check spring

The HSC inputs define the stiffness of springs used to preload the shim stack on shock compression adjusters. The HSC system also models check springs used to hold fork mid-valve shim stacks closed. Setting all inputs to zero, or blank, means there is no HSC spring operating on the shim stack.

Preload: Spring preload in [mm]. For an HSC system the preload includes static preload plus any additional preload from cranking down the compression adjuster. Shock compression adjusters generally preload the HSC spring 1 mm per turn of the adjuster.

D.hsc: Shim diameter where the HSC spring force is applied to the shim stack. The example, with D.hsc set to 10 mm, applies spring force to the first shim from the top of the stack with an outside diameter greater than or equal to 10 mm.

ReStackor draws a small box on the shim where the HSC spring force is applied as a reminder the HSC system is active and to verify the HSC spring force is applied at the correct location on the shim stack.

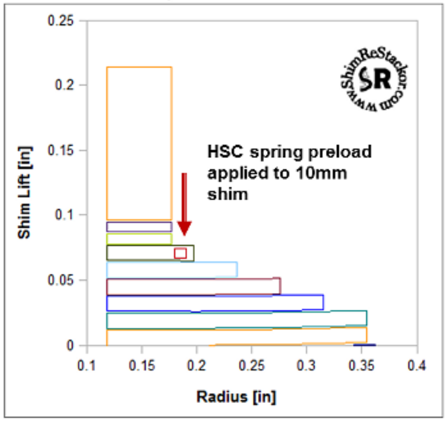


Needle	d.bleed	MAX *[clks]*	Geom File	
[mm]	0	0	D:\Needles\Showa50.in	
HSC	Preload	D.hsc	k *[kg/mm]*	
[mm]	2.5	10	8.6	
Dyno Parm	Offset	cf.stk	xL.sat	dToil
	[lbf]	*[-]*	*[-]*	*[F]*
	0	1	-0.015	0

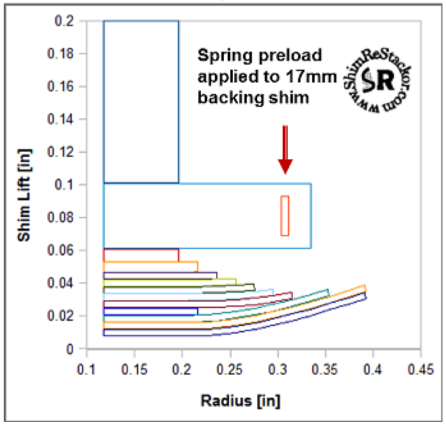
k: HSC or mid-valve spring stiffness in [kg/mm]. Little information is available on the stiffness of springs used in HSC systems, or aftermarket springs available for HSC or mid-valve check springs.

The actual stiffness can be measured or estimated using the spring design equations.

Shock HSC Spring Preload



Fork Mid-Valve Spring Preload



HSC Spring stiffness

Computing coil spring stiffness is straight forward using measurements of the spring diameter, wire diameter and number of active coils. The spring diameter is raised to the third power and the wire diameter to the fourth power making small measurement errors, like the paint thickness, significant.

Spring stiffness:

$$k_{spring} = \frac{G d_{wire}^4}{8(D_{coil} - d_{wire})^3 n_{active}} [=] \frac{kg}{mm}$$

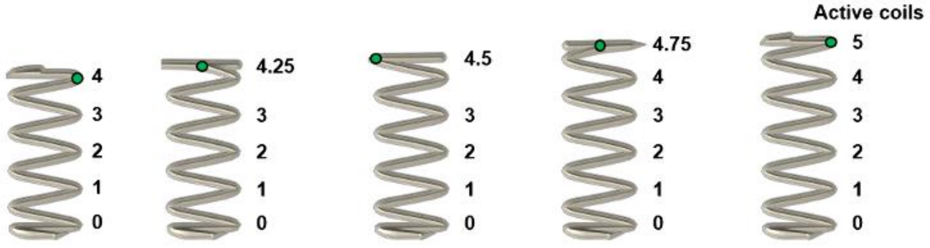
$G = 8080 \frac{kg}{mm^2}$ $\quad$ $d_{wire} = wire\ diameter, mm$

$D_{coil} = Spring\ OD, mm$ $\quad$ $n_{active} = active\ coils$

The art of computing spring stiffness is figuring out how many active coils are in the spring. At each end of the spring, the last coil is collapsed and ground flat to square the spring. The first active coil begins at the point where the wire pitch departs from the collapsed end coil. Each full revolution of the wire counts as one active coil.

The example below evaluates a coil spring with a ¾ dead wrap at each end and the number of active coils increasing from four to five.

Spring stiffness sample calculations



G	d.wire	D.coil	n.active	k.calc
[kg/mm2]	[mm]	[mm]	[#]	[kg/mm]
8080	3.6	25.3	4.00	4.15
8080	3.6	25.3	4.25	3.91
8080	3.6	25.3	4.50	3.69
8080	3.6	25.3	4.75	3.50
8080	3.6	25.3	5.00	3.32

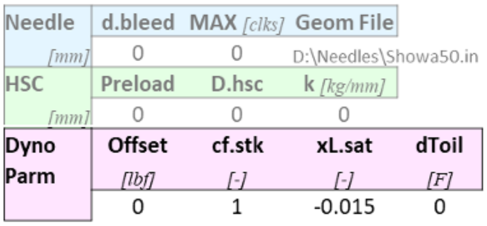
Spring stiffness:

$$k_{spring} = \frac{G d_{wire}^4}{8(D_{coil} - d_{wire})^3 n_{active}}$$

Decreasing the active coils from five to four increases the spring rate by 25%. That process of shortening the spring is used on fork springs to make the spring stiffer.

Dyno test parameters

Dyno's provide accurate damping force measurements. However, other parameters creep into dyno testing resulting in identical shock absorbers producing different damping force values. ReStackor uses four parameters to compensate for test-to-test variations in dyno damping force measurements.



Needle	d.bleed	MAX [clks]	Geom File	
[mm]	0	0	D:\Needles\Showa50.in	
HSC	Preload	D.hsc	k [kg/mm]	
[mm]	0	0	0	
Dyno Parm	Offset	cf.stk	xL.sat	dToil
	[lbf]	[-]	[-]	[F]
	0	1	-0.015	0

Offset: Seal drag and changes in the reservoir gas force as the shock heats up through the course of a test causes the zero force to drift. The Offset parameter simply adds (or subtracts) from the computed ReStackor damping force to align the zero offset force measured in dyno testing.

- Recommended value, Offset= 0.0

cf.stk: Friction between shims makes a stack stiffer during deflection and softer while closing. Friction has been measured in Belleville spring stacks to increase the spring stiffness by 30%. Through the first couple of hours of operation friction values are high as the shim surfaces mate.

That causes dyno test problems where short test durations do not allow the shim surfaces to mate resulting in measured damping force values higher than then the fielded shock operating with thoroughly broken in shim surfaces.

- Recommended value, cf.stk= 1.0

xLsat: Suspension oils contain 12% by volume dissolved gas measured as an Ostwald coefficient. The dissolved gas is in one of two states:

- **0 < xL.sat < 0.12:** Gas is dissolved in the liquid giving a clear fluid. Pressure drops through the shock circuits allow the dissolved gas to boil out and foam the oil creating a cavitation like event. The increase in volume due to the released gas causes the fluid flow to accelerate increasing the pressure drop and damping force
- **-0.12 < xLsat < 0:** Dissolved gas is released causing the oil to foam. The lower density foamed oil reduces the shock damping force
- Recommended value, xL.sat= -0.015

The shock oil reservoir pressurized to 147 psi contains 12% by volume dissolved nitrogen. When expanded back to atmospheric pressure, the 10:1 volume expansion increase the dissolved gas volume to 120% of the oil volume, severely foaming the shock oil.

dToil: Through the course of a dyno test oil temperatures heat up increasing the gas reservoir pressure, decreasing the oil viscosity and the capability of the oil to contain the dissolved gas. The dToil input increases oil temperatures with shaft velocity in ReStackor calculations to match the end of test oil temperature in PVP dyno testing.

- Recommended value, dToil= 0.0

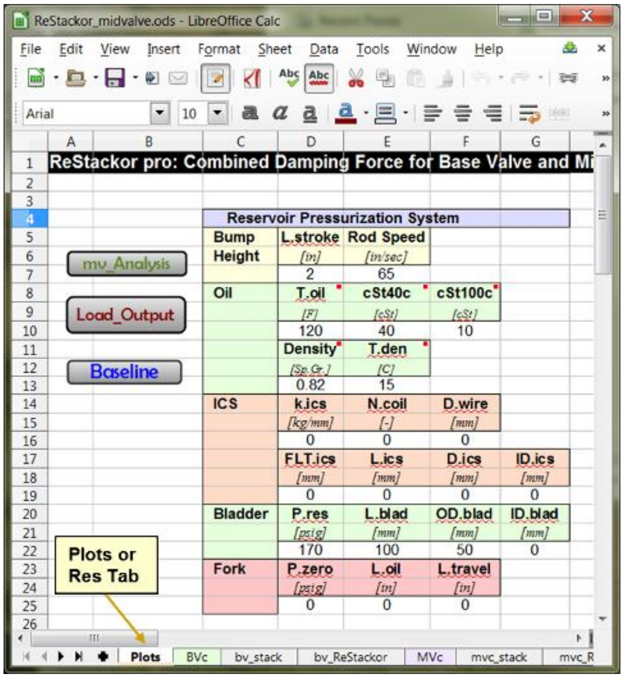
Reservoir Pressurization Systems

Reservoir pressurization inputs and the suspension oil inputs are on the “Plots” or “Res” tab of Shim ReStackor spreadsheets.

mv_Analysis: The mid-valve analysis run button on the “Plots” tab combines the damping force computed on the BVc tab for the base valve with the damping force of the mid-valve computed on the MVc tab. The combined damping force is checked and corrected for cavitation effects up to the maximum velocity specified by the “Rod Speed” input.

L.stroke: Backpressure from the shock bladder and ICS system are a function of stroke depth and computed at the stroke depth specified by the “L.stroke” input.

Rod Speed: Maximum shock absorber shaft speed for the mid-valve calculations combining the base and mid-valve damping force.



ReStackor pro: Combined Damping Force for Base Valve and Mi

Reservoir Pressurization System

Bump Height	L.stroke	Rod Speed		
	[in]	[in/sec]		
	2	65		
Oil	T.oil	cSt40c	cSt100c	
	[F]	[cSt]	[cSt]	
	120	40	10	
	Density	T.den		
	[Sp.Gr.]	[C]		
	0.82	15		
ICS	k.ics	N.coil	D.wire	
	[kg/mm]	[-]	[mm]	
	0	0	0	
	FLT.ics	L.ics	D.ics	ID.ics
	[mm]	[mm]	[mm]	[mm]
	0	0	0	0
Bladder	P.res	L.blad	OD.blad	ID.blad
	[psig]	[mm]	[mm]	[mm]
	170	100	50	0
Fork	P.zero	L.oil	L.travel	
	[psig]	[in]	[in]	
	0	0	0	

Oil Properties

T.oil: Shock absorber oil temperature

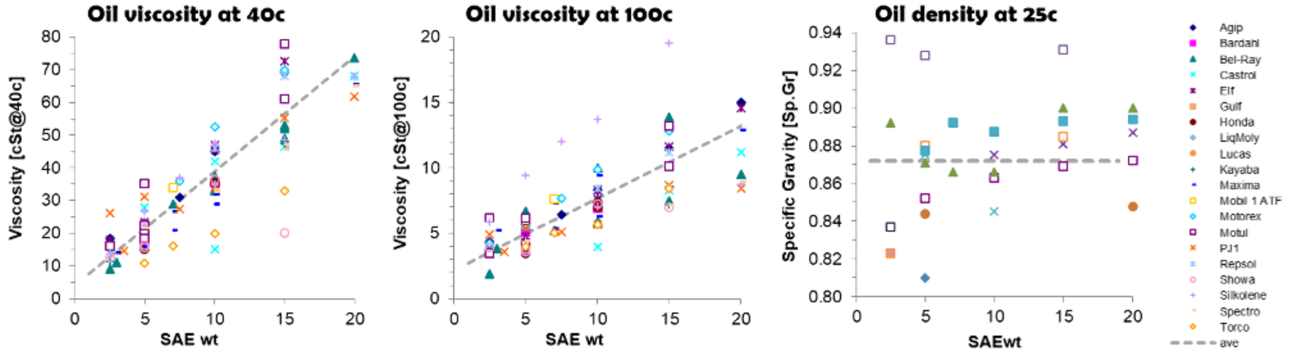
cSt.40c: Oil viscosity in centistokes measured at 40 c.

cSt.100c: Oil viscosity in centistokes measured at 100 c.

Density: Oil specific gravity relative to water. Basically equivalent to g/cc

T.den: Temperature of the oil density measurement. Typically 15 c.

Manufacturer oil viscosity data from Peter Verdone



ICS pressurization system

The ICS inputs specify the spring stiffness, float and piston diameter of the inner chamber spring pressurization system. To run an ICS configuration all of the bladder inputs must be set to zero.

K.ics: Stiffness of ICS spring, [kg/mm]. Spring stiffness can be estimated using the coil spring wire diameter.

N.coil: Number of coils in the ICS spring. ReStackor uses the number of coils and wire diameter to determine the coil bind travel limit. When the ICS spring is pushed to coil bind plastic ICS pistons will crack. The fraction of ICS stroke used is reported in the ReStackor output as Nics.

D.wire: ICS coil spring wire diameter [mm].

FLT.ics: ICS spring float at full suspension extension, [mm]. Negative float specifies spring preload.

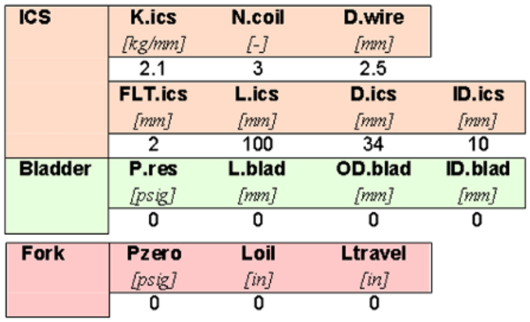
L.ics: ICS chamber length, [mm]. To specify an open chamber ICS where the fork gas pressure operates on the ICS piston the value of Lics must be zero.

D.ics: ICS piston diameter, [mm].

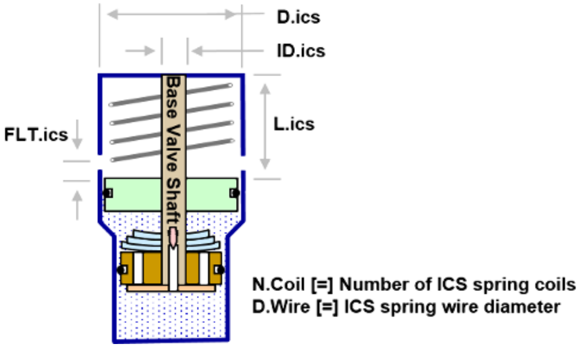
ID.ics: Shaft diameter through the ICS piston, [mm]. For a typical configuration the base valve support shaft passes through the ICS piston. This parameter specifics the shaft diameter and pressurized face area of the ICS piston.

Pzero: Pzero in the Fork section specifies the initial ICS chamber pressure at full extension of the suspension, [psig].

Fork ICS System



ICS	K.ics *[kg/mm]*	N.coil *[-]*	D.wire *[mm]*	
	2.1	3	2.5	
	FLT.ics *[mm]*	L.ics *[mm]*	D.ics *[mm]*	ID.ics *[mm]*
	2	100	34	10
Bladder	P.res *[psig]*	L.blad *[mm]*	OD.blad *[mm]*	ID.blad *[mm]*
	0	0	0	0
Fork	Pzero *[psig]*	Loil *[in]*	Ltravel *[in]*	
	0	0	0	



Closed chamber ICS: (Lics= chamber length) The ICS spring length plus float define the ICS chamber length. Pzero defines the initial chamber pressure at full extension. ICS piston motion further compresses the gas in the closed ICS chamber producing a pressure independent of the gas pressure in the fork chamber.

Open chamber ICS: (Lics= 0.0) An open chamber ICS is vented to the fork gas chamber and the Fork input values of Pzero, Loil and Ltravel defined the Fork gas spring pressure and ICS chamber pressure as a function of stroke position. Compression of the ICS spring further increases back pressure on the shock chambers.

Reservoir gas bladder

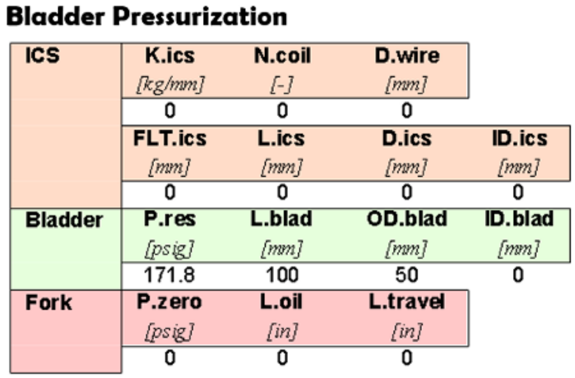
Bladder inputs specify the oil reservoir gas bladder configuration in a fork or shock. To run a bladder configuration all of the Fork and ICS inputs must be set to zero.

P.res: Initial bladder pressure at full suspension extension, [psig].

L.blad: Bladder length, [mm].

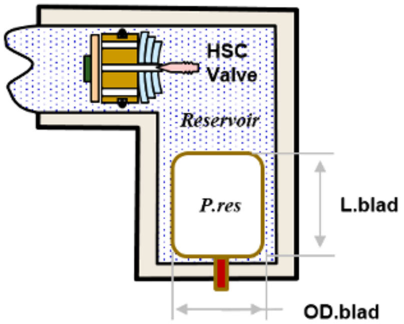
OD.blad: Bladder outside diameter, [mm].

ID.blad: Normally zero. For a fork, the bladder may have the base valve support shaft running through the bladder. In that case, ID.blad is the diameter of the shaft used to compute the gas volume inside the bladder, [mm].



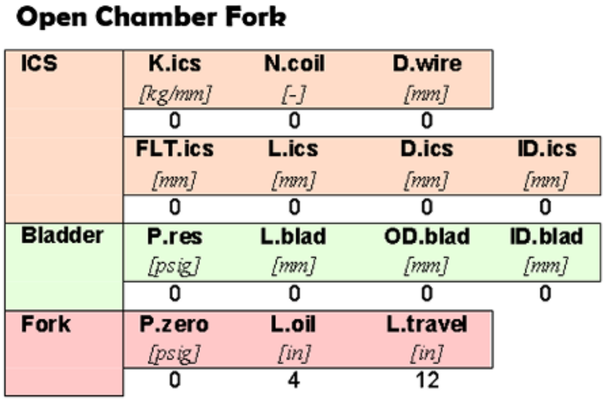
Bladder Pressurization

ICS	**K.ics** *[kg/mm]*	**N.coil** *[-]*	**D.wire** *[mm]*	
	0	0	0	
	FLT.ics *[mm]*	**L.ics** *[mm]*	**D.ics** *[mm]*	**ID.ics** *[mm]*
	0	0	0	0
Bladder	**P.res** *[psig]*	**L.blad** *[mm]*	**OD.blad** *[mm]*	**ID.blad** *[mm]*
	171.8	100	50	0
Fork	**P.zero** *[psig]*	**L.oil** *[in]*	**L.travel** *[in]*	
	0	0	0	



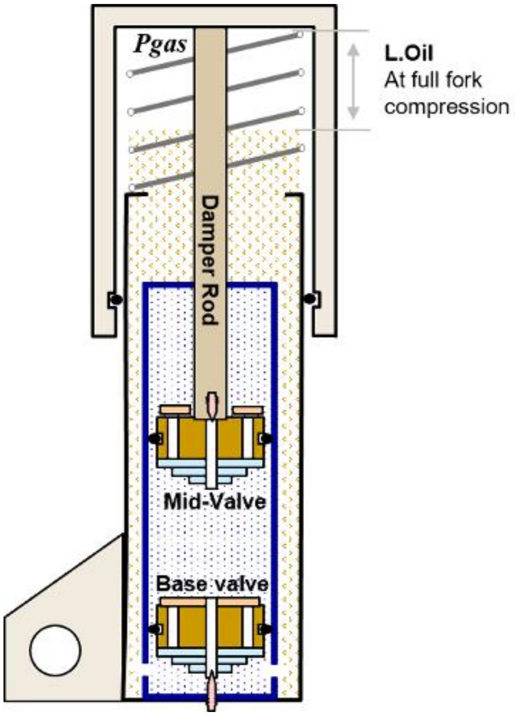
Fork oil level

The "Fork" input block defines the initial bleed pressure and oil height with the fork at full extension. To run an open chamber fork all ICS and Bladder inputs must be set to zero.



Open Chamber Fork

ICS	**K.ics** *[kg/mm]*	**N.coil** *[-]*	**D.wire** *[mm]*	
	0	0	0	
	FLT.ics *[mm]*	**L.ics** *[mm]*	**D.ics** *[mm]*	**ID.ics** *[mm]*
	0	0	0	0
Bladder	**P.res** *[psig]*	**L.blad** *[mm]*	**OD.blad** *[mm]*	**ID.blad** *[mm]*
	0	0	0	0
Fork	**P.zero** *[psig]*	**L.oil** *[in]*	**L.travel** *[in]*	
	0	4	12	



P.zero: Initial bleed pressure of the fork at full suspension extension, [psig].

L.oil: Oil height in fork measured from top of fork tube with the fork fully compressed, [in].

L.travel: Length of fork travel, [in].

Suspension response

Suspension response calculations use the compression and rebound damping force computed by Shim ReStackor on the “Mid_Valve_Calc” and “mvr_ReStackor” output tabs for compression and rebound damping.

Inputs on the suspension response tab describe the bike mass, spring rate, link ratio and suspension stroke depth to be analyzed.

Mass inputs:

m.wheel: Wheel un-sprung weight. Includes wheel, tire, brake caliper, fork stanchion tube and everything else bouncing up and down with the wheel. Putting a scale under the wheel with the fork or shock spring removed is the best way to measure un-sprung weight including all of the moving components.

Chassis: Curb weight of bike including wheel weight, fuel and accessories.

Weight split: Fraction of bike curb weight on rear wheel, w.rear/w.curb.

Spring inputs:

k.spring: Spring rate in kg/mm.

preload: Spring preload at full extension, mm.

Stroke inputs: Suspension stroke type, one of {fork, shock, front, rear}.

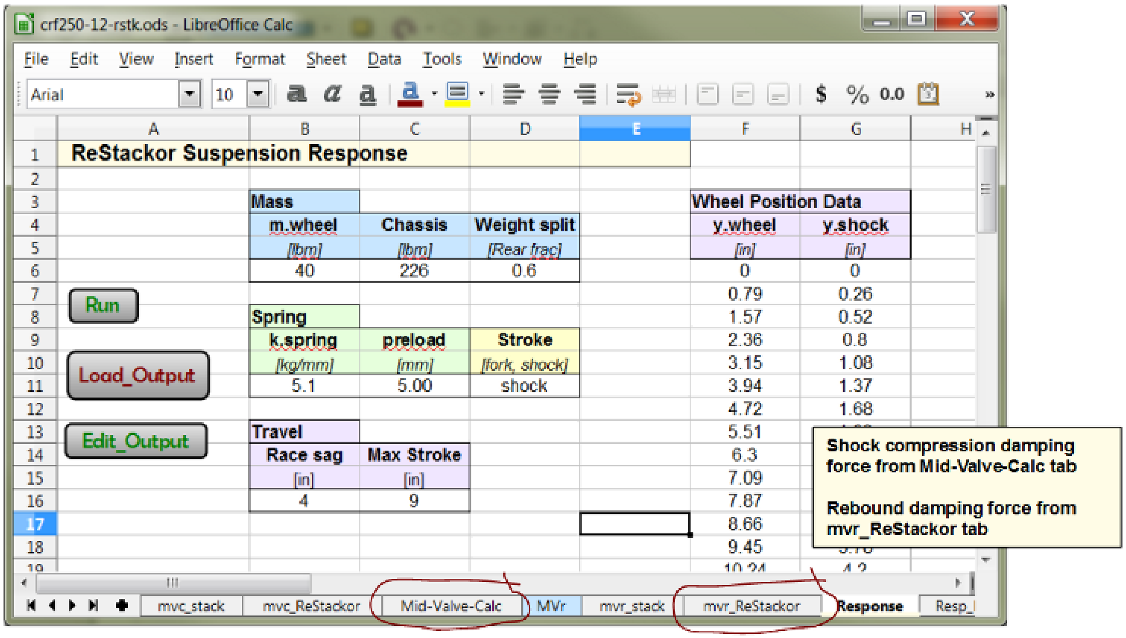
fork: Calculations assume front chassis weight is supported by two fork legs with equal damping and spring rate in each leg. For a single function fork (SFF) use the shock input below and reverse the front/rear weight spilt (1.0-Weight split).

shock: Calculations assume rear chassis weight is supported by the spring and damping of a single shock.

front: Spec for car. Calculations assume front chassis weight is supported by two shocks, two spring and two wheels.

rear: Spec for car. Calculations assume rear chassis weight is supported by two shocks, two springs and two wheels.

ReStackor suspension response inputs



ReStackor Suspension Response

Mass		
m.wheel	Chassis	Weight split
[lbm]	[lbm]	[Rear frac]
40	226	0.6

Spring		
k.spring	preload	Stroke
[kg/mm]	[mm]	[fork, shock]
5.1	5.00	shock

Travel	
Race sag	Max Stroke
[in]	[in]
4	9

Wheel Position Data	
y.wheel	y.shock
[in]	[in]
0	0
0.79	0.26
1.57	0.52
2.36	0.8
3.15	1.08
3.94	1.37
4.72	1.68
5.51	[illegible]
6.3	[illegible]
7.09	[illegible]
7.87	[illegible]
8.66	[illegible]
9.45	[illegible]

Shock compression damping force from Mid-Valve-Calc tab

Rebound damping force from mvr_ReStackor tab

Travel inputs:

Race sag: Normal suspension ride height with rider on foot pegs. Typically 1/3 of suspension travel. Shim ReStackor measures race sag as the vertical chassis displacement as typically used measuring rear sag. Fork sag is also measured as chassis sag and not stanchion tube sag.

Max Stroke: The bump stroke depth. The stroke depth must be greater than race sag and the bump rubber stroke depth is recommended as the maximum for suspension tuning.

Link ratio

Shim ReStackor computes the suspension link ratio from inputs of the wheel and shock position measurements through the suspension stroke. At least four measurements are needed with a maximum of 39 points. Using more inputs improves the fidelity of the link ratio calculation.

Wheel position inputs that fall off the average curve are labeled as “bad” in the output plot. The green “bad” points should be checked for accuracy.

Wheel Position Data:

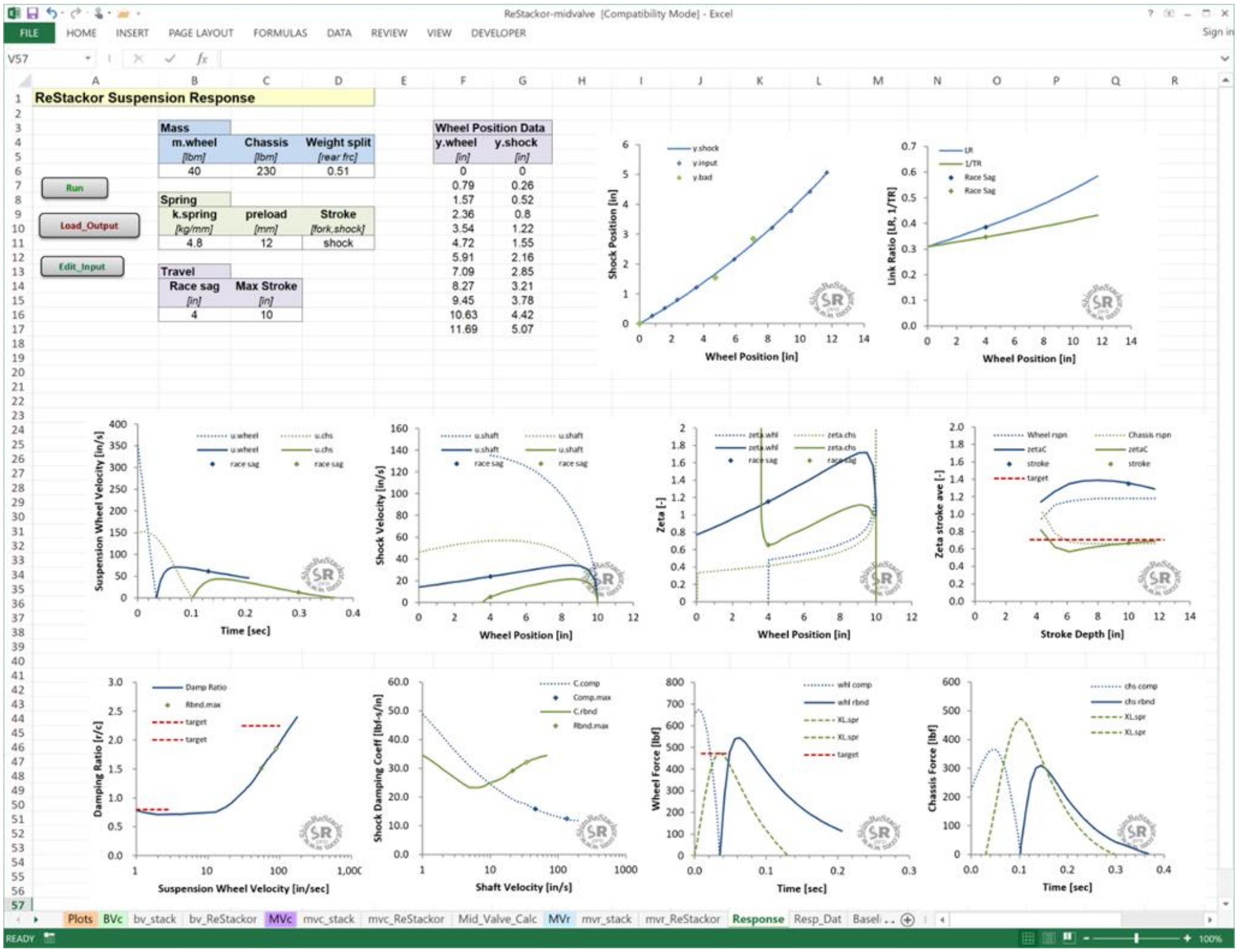
y.wheel: Wheel stroke distance measured from full extension

y.shock: Shock stroke depth measured from full extension

Fork wheel position measurements can be computed directly from the fork rake angle:

Fork wheel position:

$$y.wheel=y.shock*\cos[(\pi/180)*\text{rake angle}]$$



ReStackor Suspension Response

Mass		
m.wheel [lbm]	**Chassis** [lbm]	**Weight split** [rear frc]
40	230	0.51

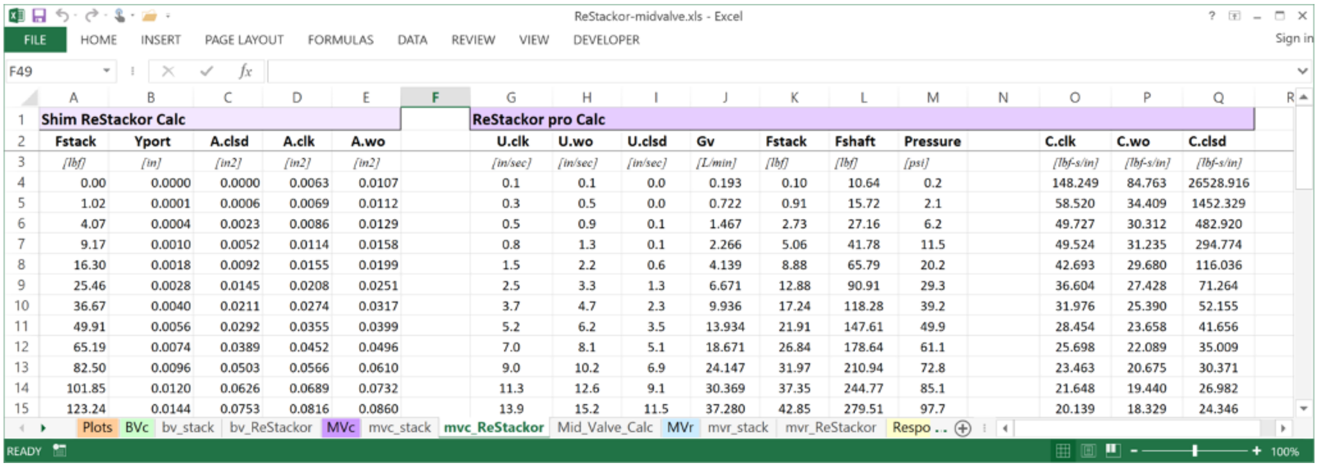
Spring		
k.spring [kg/mm]	**preload** [mm]	**Stroke** [fork,shock]
4.8	12	shock

Travel	
Race sag [in]	**Max Stroke** [in]
4	10

Wheel Position Data	
y.wheel [in]	**y.shock** [in]
0	0
0.79	0.26
1.57	0.52
2.36	0.8
3.54	1.22
4.72	1.55
5.91	2.16
7.09	2.85
8.27	3.21
9.45	3.78
10.63	4.42
11.69	5.07

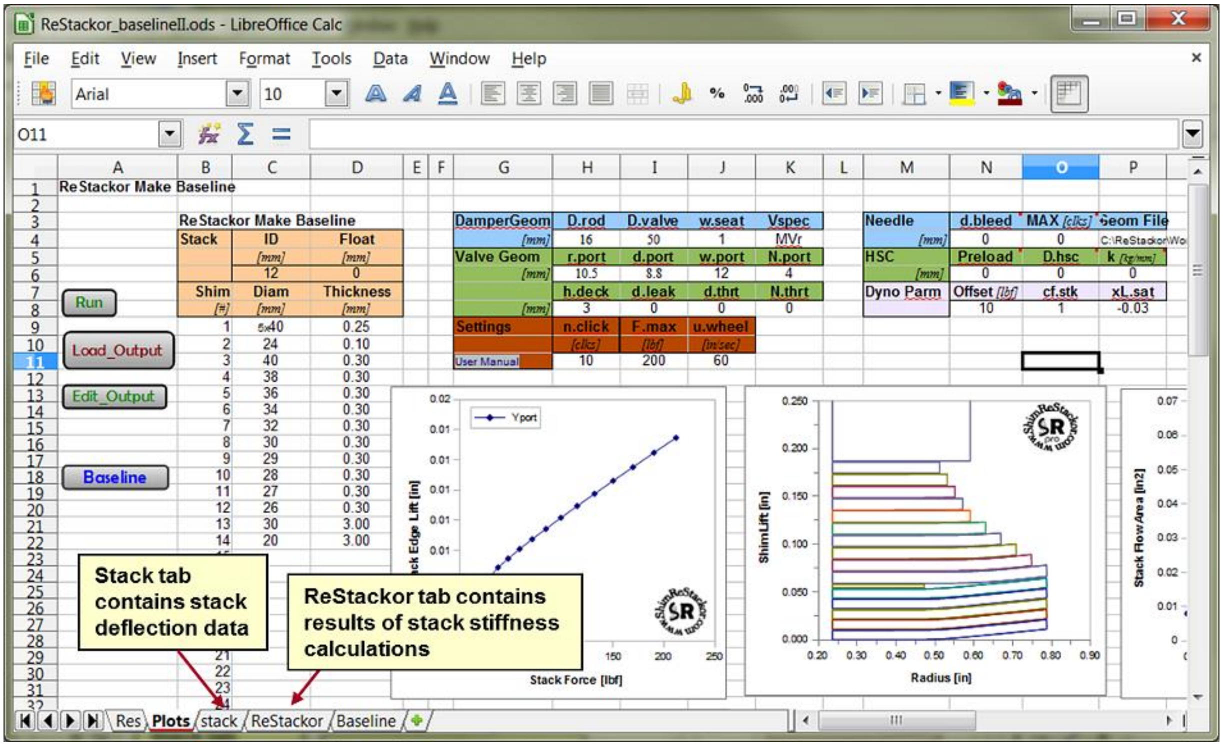
Calculation Outputs

- Shim stack deflection
- Damping force tables
- Suspension response tables



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**Shim ReStackor Calc**						**ReStackor pro Calc**										
2	**Fstack**	**Yport**	**A.clsd**	**A.clk**	**A.wo**		**U.clk**	**U.wo**	**U.clsd**	**Gv**	**Fstack**	**Fshaft**	**Pressure**		**C.clk**	**C.wo**	**C.clsd**
3	*[lbf]*	*[in]*	*[in2]*	*[in2]*	*[in2]*		*[in/sec]*	*[in/sec]*	*[in/sec]*	*[L/min]*	*[lbf]*	*[lbf]*	*[psi]*		*[lbf-s/in]*	*[lbf-s/in]*	*[lbf-s/in]*
4	0.00	0.0000	0.0000	0.0063	0.0107		0.1	0.1	0.0	0.193	0.10	10.64	0.2		148.249	84.763	26528.916
5	1.02	0.0001	0.0006	0.0069	0.0112		0.3	0.5	0.0	0.722	0.91	15.72	2.1		58.520	34.409	1452.329
6	4.07	0.0004	0.0023	0.0086	0.0129		0.5	0.9	0.1	1.467	2.73	27.16	6.2		49.727	30.312	482.920
7	9.17	0.0010	0.0052	0.0114	0.0158		0.8	1.3	0.1	2.266	5.06	41.78	11.5		49.524	31.235	294.774
8	16.30	0.0018	0.0092	0.0155	0.0199		1.5	2.2	0.6	4.139	8.88	65.79	20.2		42.693	29.680	116.036
9	25.46	0.0028	0.0145	0.0208	0.0251		2.5	3.3	1.3	6.671	12.88	90.91	29.3		36.604	27.428	71.264
10	36.67	0.0040	0.0211	0.0274	0.0317		3.7	4.7	2.3	9.936	17.24	118.28	39.2		31.976	25.390	52.155
11	49.91	0.0056	0.0292	0.0355	0.0399		5.2	6.2	3.5	13.934	21.91	147.61	49.9		28.454	23.658	41.656
12	65.19	0.0074	0.0389	0.0452	0.0496		7.0	8.1	5.1	18.671	26.84	178.64	61.1		25.698	22.089	35.009
13	82.50	0.0096	0.0503	0.0566	0.0610		9.0	10.2	6.9	24.147	31.97	210.94	72.8		23.463	20.675	30.371
14	101.85	0.0120	0.0626	0.0689	0.0732		11.3	12.6	9.1	30.369	37.35	244.77	85.1		21.648	19.440	26.982
15	123.24	0.0144	0.0753	0.0816	0.0860		13.9	15.2	11.5	37.280	42.85	279.51	97.7		20.139	18.329	24.346

Calculation Outputs



ReStackor Make Baseline

ReStackor Make Baseline

Stack	ID	Float
	[mm]	[mm]
	12	0
Shim	Diam	Thickness
[#]	[mm]	[mm]
1	5x40	0.25
2	24	0.10
3	40	0.30
4	38	0.30
5	36	0.30
6	34	0.30
7	32	0.30
8	30	0.30
9	29	0.30
10	28	0.30
11	27	0.30
12	26	0.30
13	30	3.00
14	20	3.00

DamperGeom	D.rod	D.valve	w.seat	Vspec
[mm]	16	50	1	MVr
Valve Geom	r.port	d.port	w.port	N.port
[mm]	10.5	8.8	12	4
	h.deck	d.leak	d.thrt	N.thrt
[mm]	3	0	0	0
Settings	n.click	F.max	u.wheel	
	[clks]	[lbf]	[in/sec]	
User Manual	10	200	60	

Needle	d.bleed	MAX [clks]	Geom File
[mm]	0	0	C:\ReStackor\Wo
HSC	Preload	D.hsc	k [kg/mm]
[mm]	0	0	0
Dyno Parm	Offset [lbf]	cf.stk	xL.sat
	10	1	-0.03

Stack tab contains stack deflection data

ReStackor tab contains results of stack stiffness calculations

Damping force calculations

The base valve, mid-valve compression and mid-valve rebound tabs each have separate output tabs containing tables describing the shim stack deflection and damping force computed for each valve.

Stack tab

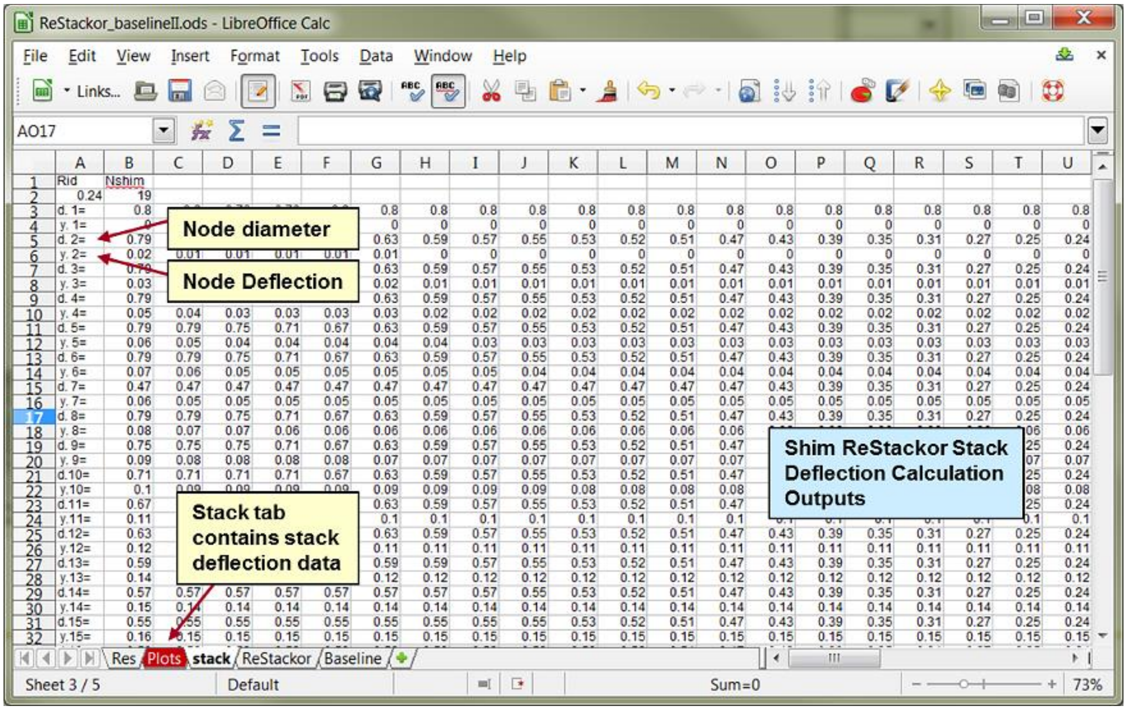
The "stack" tab of the worksheet contains data tables describing the shim stack deflection. Shim stack deflection FEA calculations solve up to 5,000 simultaneous equations balancing the radial and axial forces transmitted through the shim stack, the closure of crossover gaps and the changes in the shim bend profile as the shim stack structure deflects.

Data on the "stack" tab is simply a table describing the radius and deflection of each FEA node point in the shim stack structure.

d.n: The radius of each node point for shim n.

y.n: The deflection height of shim n at node point d.n

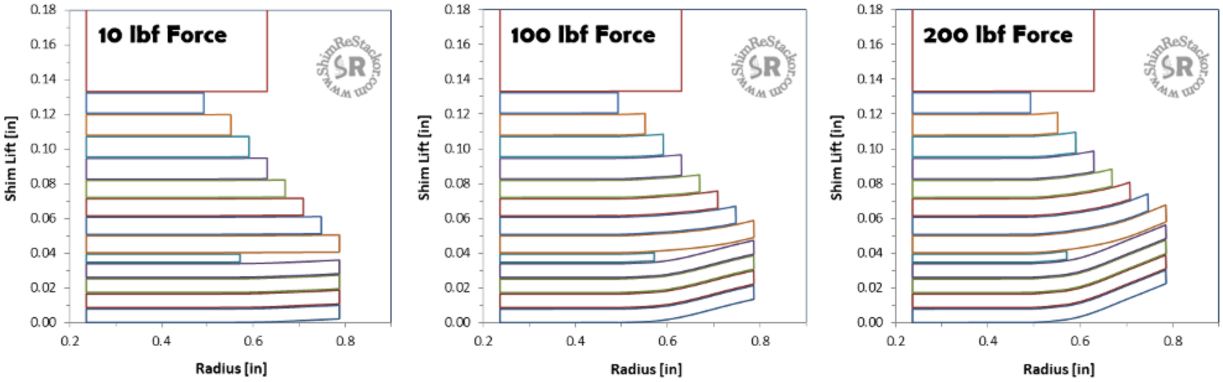
Shim stack deflection, Calculation outputs



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	Rid	Nshim																			
2	0.24	19																			
3	d. 1=	0.8	[illegible]	[illegible]	[illegible]	[illegible]	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
4	y. 1=	0	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	d. 2=	0.79	[illegible]	[illegible]	[illegible]	[illegible]	0.63	0.59	0.57	0.55	0.53	0.52	0.51	0.47	0.43	0.39	0.35	0.31	0.27	0.25	0.24
6	y. 2=	0.02	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	d. 3=	0.79	[illegible]	[illegible]	[illegible]	[illegible]	0.63	0.59	0.57	0.55	0.53	0.52	0.51	0.47	0.43	0.39	0.35	0.31	0.27	0.25	0.24
8	y. 3=	0.03	[illegible]	[illegible]	[illegible]	[illegible]	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
9	d. 4=	0.79	[illegible]	[illegible]	[illegible]	[illegible]	0.63	0.59	0.57	0.55	0.53	0.52	0.51	0.47	0.43	0.39	0.35	0.31	0.27	0.25	0.24
10	y. 4=	0.05	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
11	d. 5=	0.79	0.79	0.75	0.71	0.67	0.63	0.59	0.57	0.55	0.53	0.52	0.51	0.47	0.43	0.39	0.35	0.31	0.27	0.25	0.24
12	y. 5=	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
13	d. 6=	0.79	0.79	0.75	0.71	0.67	0.63	0.59	0.57	0.55	0.53	0.52	0.51	0.47	0.43	0.39	0.35	0.31	0.27	0.25	0.24
14	y. 6=	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
15	d. 7=	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.43	0.39	0.35	0.31	0.27	0.25	0.24
16	y. 7=	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
17	d. 8=	0.79	0.79	0.75	0.71	0.67	0.63	0.59	0.57	0.55	0.53	0.52	0.51	0.47	0.43	0.39	0.35	0.31	0.27	0.25	0.24
18	y. 8=	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.06
19	d. 9=	0.75	0.75	0.75	0.71	0.67	0.63	0.59	0.57	0.55	0.53	0.52	0.51	0.47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.24
20	y. 9=	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.07
21	d.10=	0.71	0.71	0.71	0.71	0.67	0.63	0.59	0.57	0.55	0.53	0.52	0.51	0.47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.24
22	y.10=	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.08
23	d.11=	0.67	[illegible]	[illegible]	[illegible]	[illegible]	0.63	0.59	0.57	0.55	0.53	0.52	0.51	0.47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.24
24	y.11=	0.11	[illegible]	[illegible]	[illegible]	[illegible]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.1
25	d.12=	0.63	[illegible]	[illegible]	[illegible]	[illegible]	0.63	0.59	0.57	0.55	0.53	0.52	0.51	0.47	0.43	0.39	0.35	0.31	0.27	0.25	0.24
26	y.12=	0.12	[illegible]	[illegible]	[illegible]	[illegible]	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
27	d.13=	0.59	[illegible]	[illegible]	[illegible]	[illegible]	0.59	0.59	0.57	0.55	0.53	0.52	0.51	0.47	0.43	0.39	0.35	0.31	0.27	0.25	0.24
28	y.13=	0.14	[illegible]	[illegible]	[illegible]	[illegible]	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
29	d.14=	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.55	0.53	0.52	0.51	0.47	0.43	0.39	0.35	0.31	0.27	0.25	0.24
30	y.14=	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
31	d.15=	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.53	0.52	0.51	0.47	0.43	0.39	0.35	0.31	0.27	0.25	0.24
32	y.15=	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

Figure 8: Shim stack deflection output table. Vertical deflection of each shim as a function of radial position

The above table is far more interesting when viewed as a plot. Running ReStackor with the stack force set to 0, 100 and 200 lbf produces the sequence of plots shown below. Shim stack deflection graphics help visualize the stack structure, the effect of shim changes in clamp diameter, stack taper, crossover gaps and the influence of changes in the shim stack structure on the shape of the damping force curve.



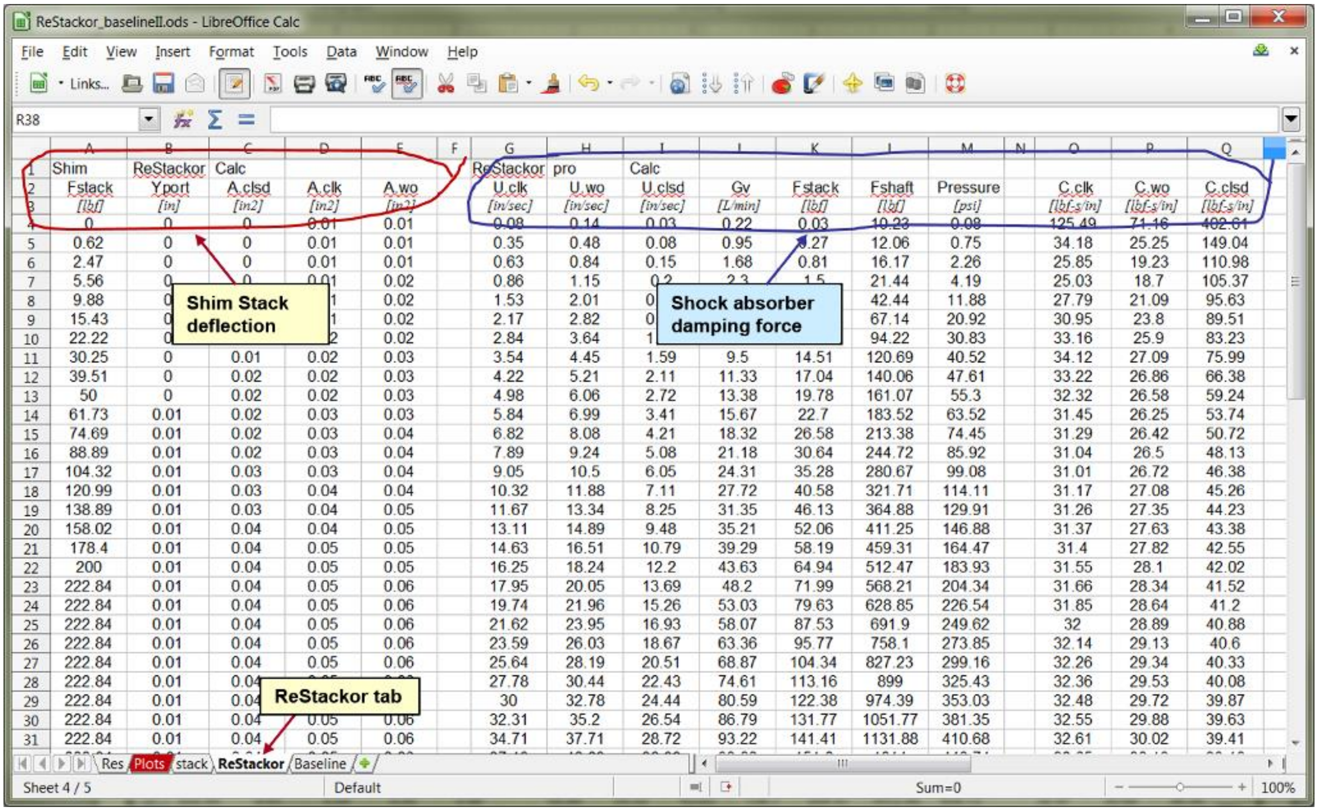
Damping force outputs

The computed shock absorber damping force is loaded into the "ReStackor" tab of the spreadsheet.

- Columns A through E contain the shim stack deflection at a given applied fluid force
- Columns G through Q contain the damping force computed for the shock absorber

Shim stack deflection

Calculations start with zero fluid force applied to the shim stack. The output table lists the shim stack deflection with progressively higher fluid force applied to the shim stack face up to the maximum specified by the input F.stack parameter. ReStackor increments the force using a logarithmic function focusing more points at low force to accurately describe how the shim stack cracks open.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Shim	ReStackor	Calc				ReStackor	pro	Calc								
2	Fstack	Yport	A.clsd	A.clk	A.wo		U.clk	U.wo	U.clsd	Gv	Fstack	Fshaft	Pressure		C.clk	C.wo	C.clsd
3	[lbf]	[in]	[in2]	[in2]	[in2]		[in/sec]	[in/sec]	[in/sec]	[L/min]	[lbf]	[lbf]	[psi]		[lbf-s/in]	[lbf-s/in]	[lbf-s/in]
4	0	0	0	0.01	0.01		0.08	0.14	0.03	0.22	0.03	10.23	0.08		125.49	71.16	402.61
5	0.62	0	0	0.01	0.01		0.35	0.48	0.08	0.95	0.27	12.06	0.75		34.18	25.25	149.04
6	2.47	0	0	0.01	0.01		0.63	0.84	0.15	1.68	0.81	16.17	2.26		25.85	19.23	110.98
7	5.56	0	0	0.01	0.02		0.86	1.15	0.2	2.3	1.5	21.44	4.19		25.03	18.7	105.37
8	9.88	0	[illegible]	[illegible]	0.02		1.53	2.01	[illegible]	[illegible]	[illegible]	42.44	11.88		27.79	21.09	95.63
9	15.43	0	[illegible]	[illegible]	0.02		2.17	2.82	[illegible]	[illegible]	[illegible]	67.14	20.92		30.95	23.8	89.51
10	22.22	0	[illegible]	[illegible]	0.02		2.84	3.64	[illegible]	[illegible]	[illegible]	94.22	30.83		33.16	25.9	83.23
11	30.25	0	0.01	0.02	0.03		3.54	4.45	1.59	9.5	14.51	120.69	40.52		34.12	27.09	75.99
12	39.51	0	0.02	0.02	0.03		4.22	5.21	2.11	11.33	17.04	140.06	47.61		33.22	26.86	66.38
13	50	0	0.02	0.02	0.03		4.98	6.06	2.72	13.38	19.78	161.07	55.3		32.32	26.58	59.24
14	61.73	0.01	0.02	0.03	0.03		5.84	6.99	3.41	15.67	22.7	183.52	63.52		31.45	26.25	53.74
15	74.69	0.01	0.02	0.03	0.04		6.82	8.08	4.21	18.32	26.58	213.38	74.45		31.29	26.42	50.72
16	88.89	0.01	0.02	0.03	0.04		7.89	9.24	5.08	21.18	30.64	244.72	85.92		31.04	26.5	48.13
17	104.32	0.01	0.03	0.03	0.04		9.05	10.5	6.05	24.31	35.28	280.67	99.08		31.01	26.72	46.38
18	120.99	0.01	0.03	0.04	0.04		10.32	11.88	7.11	27.72	40.58	321.71	114.11		31.17	27.08	45.26
19	138.89	0.01	0.03	0.04	0.05		11.67	13.34	8.25	31.35	46.13	364.88	129.91		31.26	27.35	44.23
20	158.02	0.01	0.04	0.04	0.05		13.11	14.89	9.48	35.21	52.06	411.25	146.88		31.37	27.63	43.38
21	178.4	0.01	0.04	0.05	0.05		14.63	16.51	10.79	39.29	58.19	459.31	164.47		31.4	27.82	42.55
22	200	0.01	0.04	0.05	0.05		16.25	18.24	12.2	43.63	64.94	512.47	183.93		31.55	28.1	42.02
23	222.84	0.01	0.04	0.05	0.06		17.95	20.05	13.69	48.2	71.99	568.21	204.34		31.66	28.34	41.52
24	222.84	0.01	0.04	0.05	0.06		19.74	21.96	15.26	53.03	79.63	628.85	226.54		31.85	28.64	41.2
25	222.84	0.01	0.04	0.05	0.06		21.62	23.95	16.93	58.07	87.53	691.9	249.62		32	28.89	40.88
26	222.84	0.01	0.04	0.05	0.06		23.59	26.03	18.67	63.36	95.77	758.1	273.85		32.14	29.13	40.6
27	222.84	0.01	0.04	0.05	0.06		25.64	28.19	20.51	68.87	104.34	827.23	299.16		32.26	29.34	40.33
28	222.84	0.01	0.04	[illegible]	[illegible]		27.78	30.44	22.43	74.61	113.16	899	325.43		32.36	29.53	40.08
29	222.84	0.01	0.04	[illegible]	[illegible]		30	32.78	24.44	80.59	122.38	974.39	353.03		32.48	29.72	39.87
30	222.84	0.01	0.04	0.05	0.06		32.31	35.2	26.54	86.79	131.77	1051.77	381.35		32.55	29.88	39.63
31	222.84	0.01	0.04	0.05	0.06		34.71	37.71	28.72	93.22	141.41	1131.88	410.68		32.61	30.02	39.41

Fstack: Force applied to the stack face shim, [lbf].

Yport: Edge lift of the stack measured at the outer edge of the valve port, [inches]. The port outer edge is defined by the input parameters r.port + d.port.

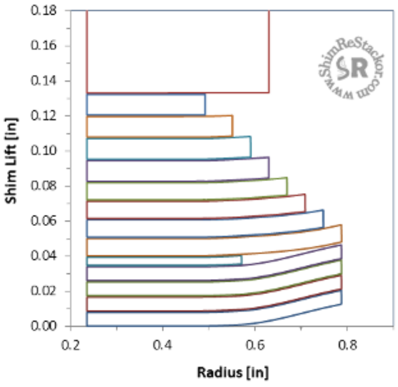
A.clsd: The fluid flow area between the valve face and shim stack [square inches]. This measurement is taken with the clickers closed. The flow area is controlled by shim stack deflection and the specifics of the valve port geometry configuration.

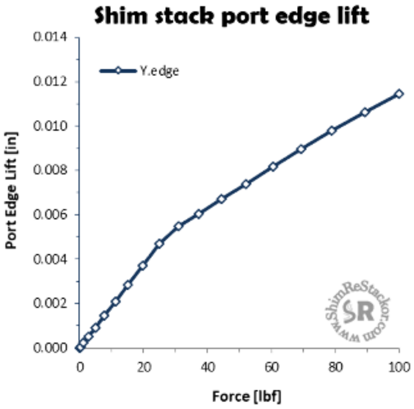
A.clk: The stack flow area as defined above, plus the flow area through the clicker bleed circuit at the input clicker position, [square inches].

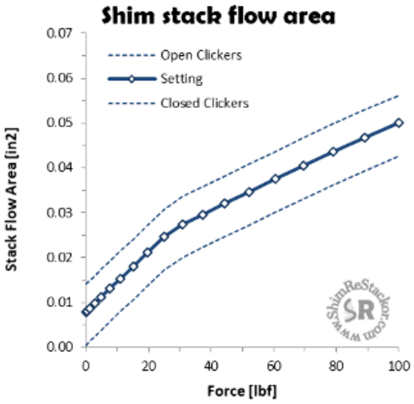
A.wo: The stack face flow area as defined above, plus the clicker flow area at the wide open clicker position, [square inches].

Shim stack deflection plots

The above calculation outputs are plotted on the output tab for each valve showing the stack edge lift and flow area as a function of fluid force applied to the stack. The stack fluid force as a function of shock absorber shaft velocity is listed in column K.

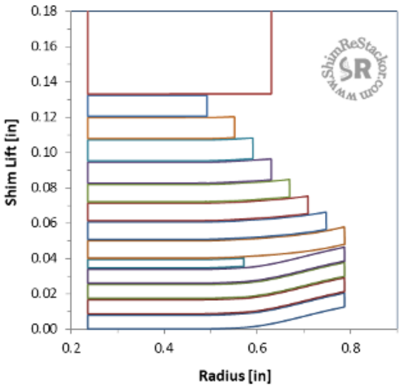


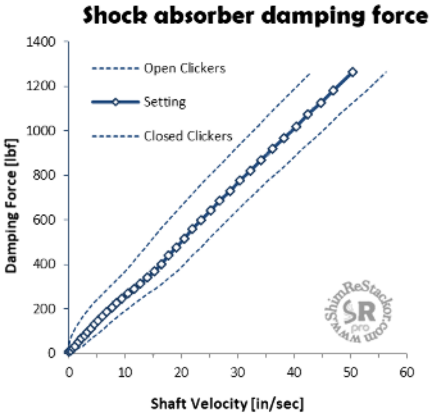


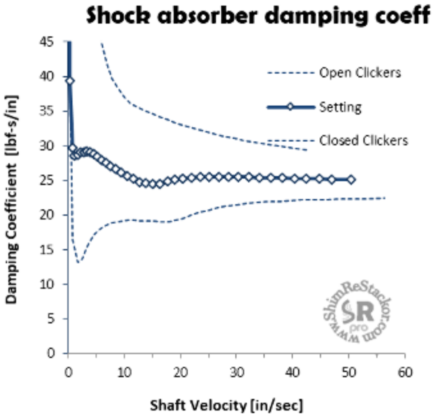


Damping force plots

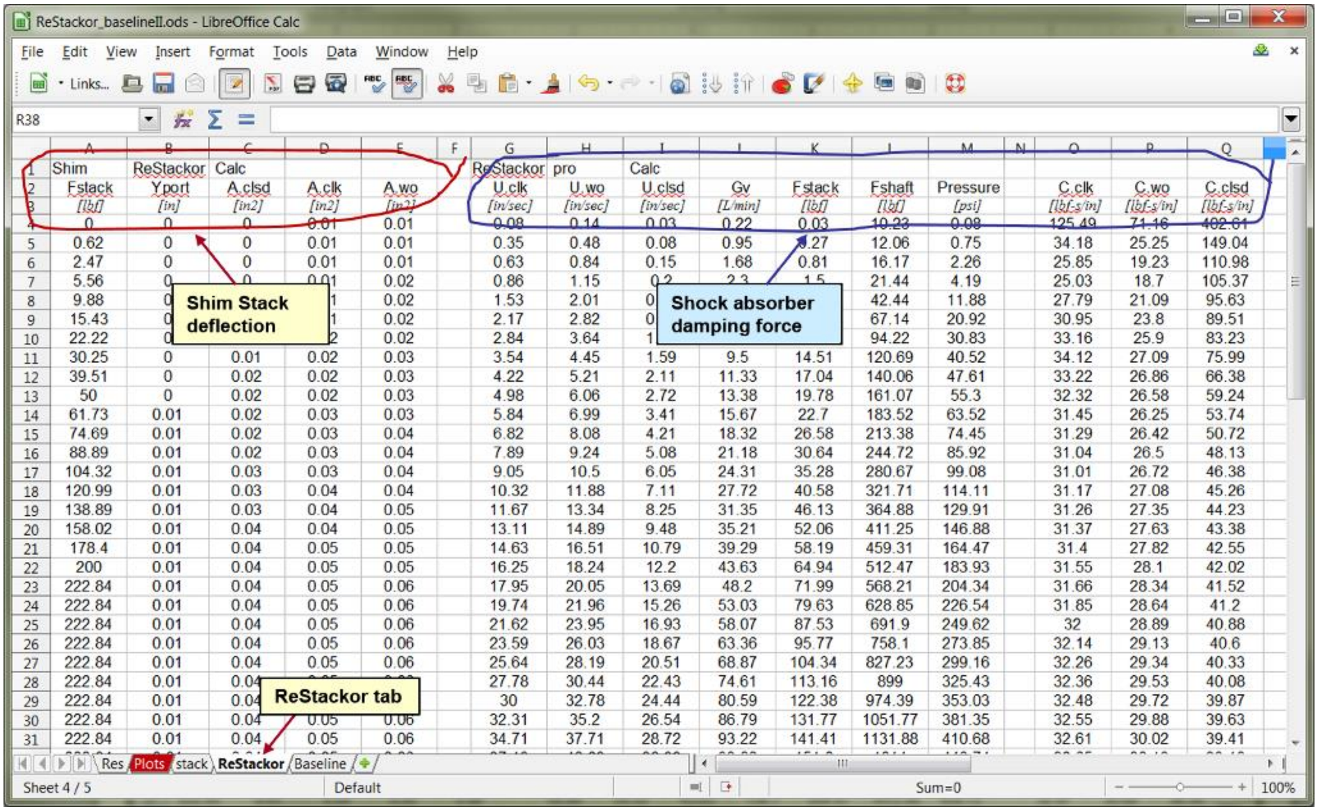
Damping force outputs from Shim ReStackor calculations are listed in columns G through Q providing the data plotted in the output damping force curves.







Damping force outputs



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Shim	ReStackor	Calc				ReStackor	pro	Calc								
2	Fstack	Yport	A.clsd	A.clk	A.wo		U.clk	U.wo	U.clsd	Gv	Fstack	Fshaft	Pressure		C.clk	C.wo	C.clsd
3	[lbf]	[in]	[in2]	[in2]	[in2]		[in/sec]	[in/sec]	[in/sec]	[L/min]	[lbf]	[lbf]	[psi]		[lbf-s/in]	[lbf-s/in]	[lbf-s/in]
4	0	0	0	0.01	0.01		0.08	0.14	0.03	0.22	0.03	10.23	0.08		125.49	71.16	402.61
5	0.62	0	0	0.01	0.01		0.35	0.48	0.08	0.95	[illegible]	12.06	0.75		34.18	25.25	149.04
6	2.47	0	0	0.01	0.01		0.63	0.84	0.15	1.68	0.81	16.17	2.26		25.85	19.23	110.98
7	5.56	0	0	0.01	0.02		0.86	1.15	0.2	2.3	1.5	21.44	4.19		25.03	18.7	105.37
8	9.88	0	[illegible]	[illegible]	0.02		1.53	2.01	[illegible]	[illegible]	[illegible]	42.44	11.88		27.79	21.09	95.63
9	15.43	0	[illegible]	[illegible]	0.02		2.17	2.82	[illegible]	[illegible]	[illegible]	67.14	20.92		30.95	23.8	89.51
10	22.22	0	[illegible]	[illegible]	0.02		2.84	3.64	[illegible]	[illegible]	[illegible]	94.22	30.83		33.16	25.9	83.23
11	30.25	0	0.01	0.02	0.03		3.54	4.45	1.59	9.5	14.51	120.69	40.52		34.12	27.09	75.99
12	39.51	0	0.02	0.02	0.03		4.22	5.21	2.11	11.33	17.04	140.06	47.61		33.22	26.86	66.38
13	50	0	0.02	0.02	0.03		4.98	6.06	2.72	13.38	19.78	161.07	55.3		32.32	26.58	59.24
14	61.73	0.01	0.02	0.03	0.03		5.84	6.99	3.41	15.67	22.7	183.52	63.52		31.45	26.25	53.74
15	74.69	0.01	0.02	0.03	0.04		6.82	8.08	4.21	18.32	26.58	213.38	74.45		31.29	26.42	50.72
16	88.89	0.01	0.02	0.03	0.04		7.89	9.24	5.08	21.18	30.64	244.72	85.92		31.04	26.5	48.13
17	104.32	0.01	0.03	0.03	0.04		9.05	10.5	6.05	24.31	35.28	280.67	99.08		31.01	26.72	46.38
18	120.99	0.01	0.03	0.04	0.04		10.32	11.88	7.11	27.72	40.58	321.71	114.11		31.17	27.08	45.26
19	138.89	0.01	0.03	0.04	0.05		11.67	13.34	8.25	31.35	46.13	364.88	129.91		31.26	27.35	44.23
20	158.02	0.01	0.04	0.04	0.05		13.11	14.89	9.48	35.21	52.06	411.25	146.88		31.37	27.63	43.38
21	178.4	0.01	0.04	0.05	0.05		14.63	16.51	10.79	39.29	58.19	459.31	164.47		31.4	27.82	42.55
22	200	0.01	0.04	0.05	0.05		16.25	18.24	12.2	43.63	64.94	512.47	183.93		31.55	28.1	42.02
23	222.84	0.01	0.04	0.05	0.06		17.95	20.05	13.69	48.2	71.99	568.21	204.34		31.66	28.34	41.52
24	222.84	0.01	0.04	0.05	0.06		19.74	21.96	15.26	53.03	79.63	628.85	226.54		31.85	28.64	41.2
25	222.84	0.01	0.04	0.05	0.06		21.62	23.95	16.93	58.07	87.53	691.9	249.62		32	28.89	40.88
26	222.84	0.01	0.04	0.05	0.06		23.59	26.03	18.67	63.36	95.77	758.1	273.85		32.14	29.13	40.6
27	222.84	0.01	0.04	0.05	0.06		25.64	28.19	20.51	68.87	104.34	827.23	299.16		32.26	29.34	40.33
28	222.84	0.01	0.04	[illegible]	[illegible]		27.78	30.44	22.43	74.61	113.16	899	325.43		32.36	29.53	40.08
29	222.84	0.01	0.04	[illegible]	[illegible]		30	32.78	24.44	80.59	122.38	974.39	353.03		32.48	29.72	39.87
30	222.84	0.01	0.04	0.05	0.06		32.31	35.2	26.54	86.79	131.77	1051.77	381.35		32.55	29.88	39.63
31	222.84	0.01	0.04	0.05	0.06		34.71	37.71	28.72	93.22	141.41	1131.88	410.68		32.61	30.02	39.41

U.clk: The shock absorber damper rod velocity [inches/sec] with the clickers set at the input n.click position. ReStackor calculations determine the flow split between the bleed circuit and valve, fluid dynamic forces acting on the shim stack face and resulting stack deflection controlling the damping force produced by the shock.

U.wo: The shock absorber damper rod velocity [inches/sec] with the clickers in the wide open position. The difference between U.clk and U.wo is the fluid flow through the clicker bleed circuit. With the clickers wide open a higher suspension velocity is needed to make up for the additional flow through the clicker bleed circuit.

U.clsd: The shock absorber damper rod velocity [inches/sec] with the clickers in the closed position. The difference between Uclk and Uclsd is there is no flow through the bleed circuit.

Gv: The fluid flow rate through the combined valve and bleed circuits [liters/min].

Fstack: The fluid force applied to the shim stack face [lbf].

Fshaft: The damping force produced by the shock at the given shaft velocity [lbf].

Pressure: The pressure drop across the valve [psi]. This is the pressure difference across the valve, not the chamber pressure.

C.clk: Damping coefficient with clickers set at the requested position. The damping coefficient is defined as the shock absorber damping force divided by the shaft velocity [lbf-sec/in]

C.wo: Damping coefficient with the clickers wide open. [lbf-sec/in]

C.clsd: Damping coefficient with the clickers closed. [lbf-sec/in]

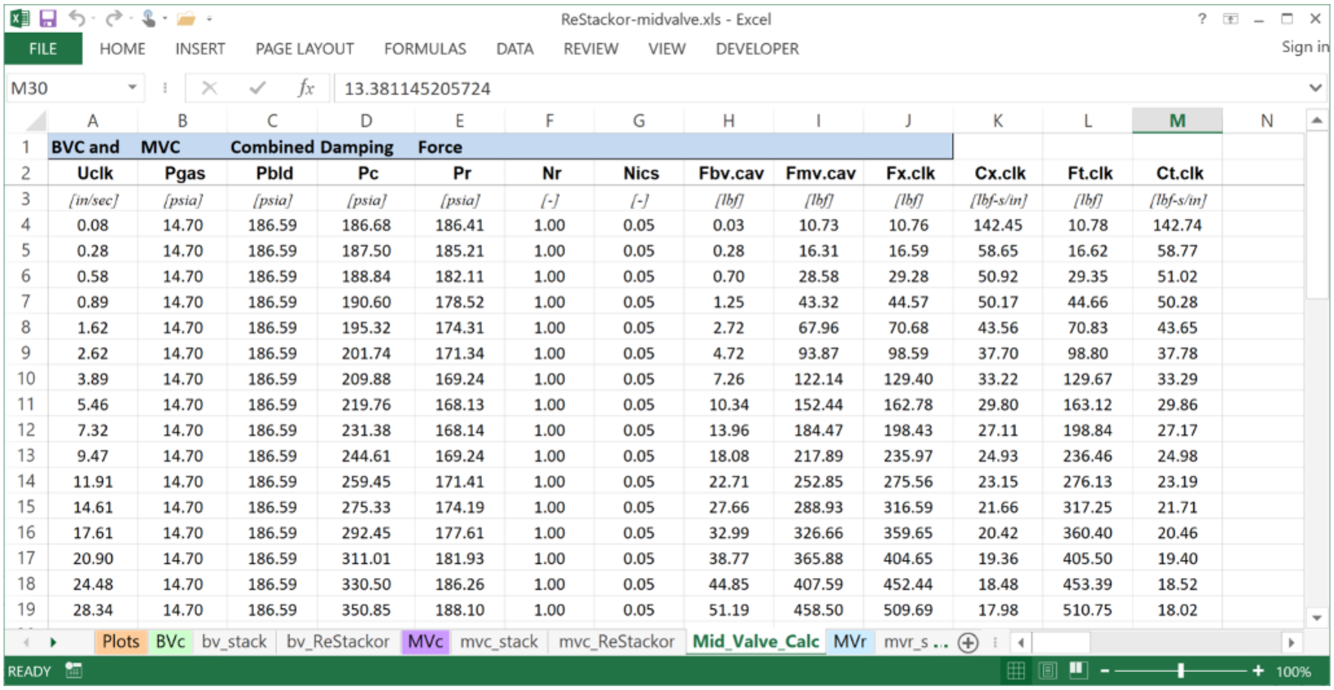
Mid-valve damping force

The "mv_Analysis" button on the Plots tab of ReStackor-midvalve spreadsheets combine the mid-valve and base valve (or compression adjuster) damping force to determine the overall compression damping force of the shock absorber.

Under non-cavitating conditions, the combined damping force is simply the sum of the base and mid-valve. Under cavitating conditions release of dissolved gas foams the oil and alters the flow rate and pressure drop through the valve driving damping force up or down depending on the severity of the cavitation.

ReStackor "mv_Analysis" calculations track the flow through each valve enforcing conservation of fluid mass and volume to determine the change in valve flow and damping force as the severity of cavitation increases.

The "mv_Analysis" calculations also determine the chamber pressure and backpressure required to "pressure balance" the shock chambers for suppression of cavitation oil foaming. Operation under "pressure balanced" conditions is recommended to obtain repeatable and reliable performance from the shock in a cavitation free environment.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	BVC and	MVC	Combined Damping		Force									
2	Uclk	Pgas	Pbld	Pc	Pr	Nr	Nics	Fbv.cav	Fmv.cav	Fx.clk	Cx.clk	Ft.clk	Ct.clk	
3	[in/sec]	[psia]	[psia]	[psia]	[psia]	[-]	[-]	[lbf]	[lbf]	[lbf]	[lbf-s/in]	[lbf]	[lbf-s/in]	
4	0.08	14.70	186.59	186.68	186.41	1.00	0.05	0.03	10.73	10.76	142.45	10.78	142.74	
5	0.28	14.70	186.59	187.50	185.21	1.00	0.05	0.28	16.31	16.59	58.65	16.62	58.77	
6	0.58	14.70	186.59	188.84	182.11	1.00	0.05	0.70	28.58	29.28	50.92	29.35	51.02	
7	0.89	14.70	186.59	190.60	178.52	1.00	0.05	1.25	43.32	44.57	50.17	44.66	50.28	
8	1.62	14.70	186.59	195.32	174.31	1.00	0.05	2.72	67.96	70.68	43.56	70.83	43.65	
9	2.62	14.70	186.59	201.74	171.34	1.00	0.05	4.72	93.87	98.59	37.70	98.80	37.78	
10	3.89	14.70	186.59	209.88	169.24	1.00	0.05	7.26	122.14	129.40	33.22	129.67	33.29	
11	5.46	14.70	186.59	219.76	168.13	1.00	0.05	10.34	152.44	162.78	29.80	163.12	29.86	
12	7.32	14.70	186.59	231.38	168.14	1.00	0.05	13.96	184.47	198.43	27.11	198.84	27.17	
13	9.47	14.70	186.59	244.61	169.24	1.00	0.05	18.08	217.89	235.97	24.93	236.46	24.98	
14	11.91	14.70	186.59	259.45	171.41	1.00	0.05	22.71	252.85	275.56	23.15	276.13	23.19	
15	14.61	14.70	186.59	275.33	174.19	1.00	0.05	27.66	288.93	316.59	21.66	317.25	21.71	
16	17.61	14.70	186.59	292.45	177.61	1.00	0.05	32.99	326.66	359.65	20.42	360.40	20.46	
17	20.90	14.70	186.59	311.01	181.93	1.00	0.05	38.77	365.88	404.65	19.36	405.50	19.40	
18	24.48	14.70	186.59	330.50	186.26	1.00	0.05	44.85	407.59	452.44	18.48	453.39	18.52	
19	28.34	14.70	186.59	350.85	188.10	1.00	0.05	51.19	458.50	509.69	17.98	510.75	18.02	

U.clk: Suspension damper rod velocity with the base valve and mid-valve clickers set at the requested position on the BVc and MVc input tabs.

Pgas: Bladder gas pressure or pressure above the ICS piston in the fluid reservoir of the shock or fork, [psia].

Pfrk: Pressure in the shock fluid reservoir; [psia]. The parameter name in this column will change from Pfrk to Pics or Pbld (bladder) depending on the configuration of the reservoir pressurization system used in the calculation.

Pc: Fluid pressure in the shock compression chamber, [psia]

Pr: Fluid pressure in the rebound chamber, [psia].

Nr: Fraction of rebound chamber filled with fluid.

Nics: Fraction of ICS stroke or bladder volume used at current suspension stroke.

Fbv.cav: Damping force produced by base valve, if the shock is cavitating this force will be different from the non-cavitating damping force computed on the bv_ReStackor tab, [lbf].

Fmv.cav: Damping force produced by mid-valve, if the shock is cavitating this force will be different from the non-cavitating damping force computed on the mv_ReStackor tab, [lbf].

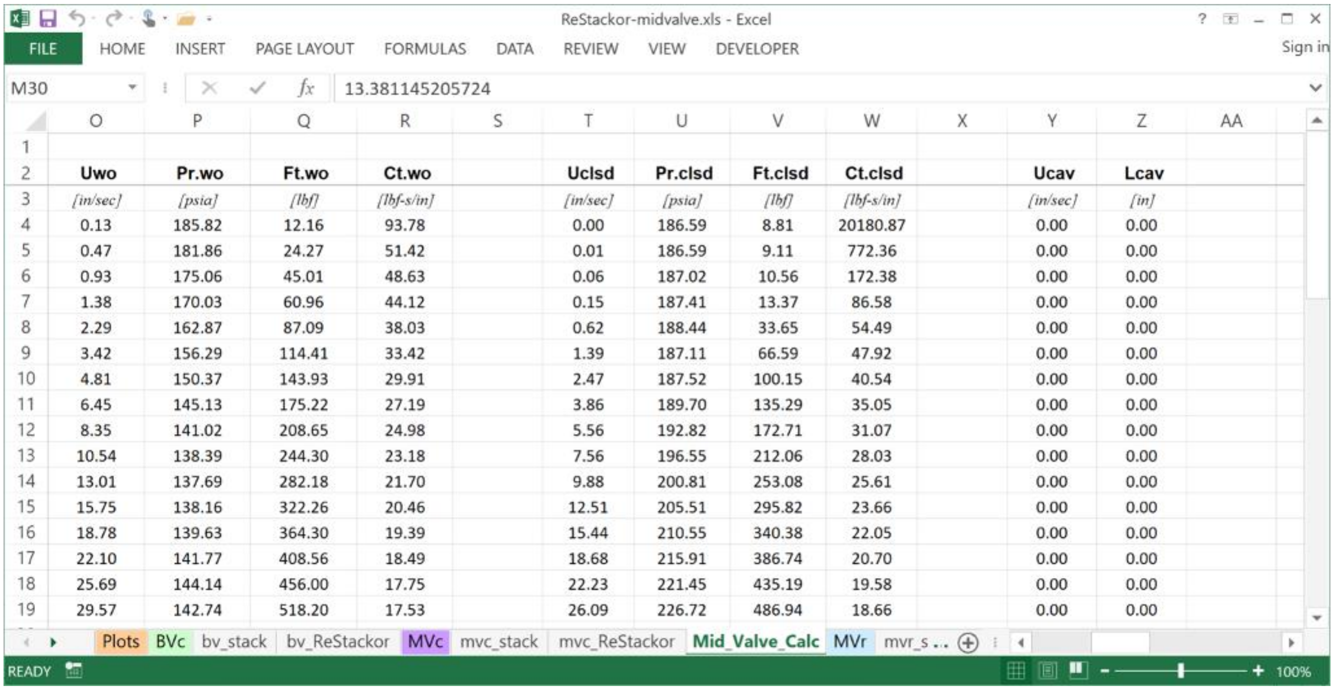
Fx.clk: Damping force produced at the stroke depth specified by the Lstroke input, [lbf].

Cx.clk: Damping coefficient at the stroke depth specified by the Lstroke input, [lbf-sec/in].

Ft.clk: Combined damping force of base and mid-valve integrated over the specified stroke depth, [lbf].

Ct.clk: Damping coefficient of combined base and mid-valve damping force integrated over specified stroke depth, [lbf-sec/in].

Open and closed clicker damping force



M30 f_x 13.381145205724

	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
1													
2	Uwo	Pr.wo	Ft.wo	Ct.wo		Uclsd	Pr.clsd	Ft.clsd	Ct.clsd		Ucav	Lcav	
3	[in/sec]	[psia]	[lbf]	[lbf-s/in]		[in/sec]	[psia]	[lbf]	[lbf-s/in]		[in/sec]	[in]	
4	0.13	185.82	12.16	93.78		0.00	186.59	8.81	20180.87		0.00	0.00	
5	0.47	181.86	24.27	51.42		0.01	186.59	9.11	772.36		0.00	0.00	
6	0.93	175.06	45.01	48.63		0.06	187.02	10.56	172.38		0.00	0.00	
7	1.38	170.03	60.96	44.12		0.15	187.41	13.37	86.58		0.00	0.00	
8	2.29	162.87	87.09	38.03		0.62	188.44	33.65	54.49		0.00	0.00	
9	3.42	156.29	114.41	33.42		1.39	187.11	66.59	47.92		0.00	0.00	
10	4.81	150.37	143.93	29.91		2.47	187.52	100.15	40.54		0.00	0.00	
11	6.45	145.13	175.22	27.19		3.86	189.70	135.29	35.05		0.00	0.00	
12	8.35	141.02	208.65	24.98		5.56	192.82	172.71	31.07		0.00	0.00	
13	10.54	138.39	244.30	23.18		7.56	196.55	212.06	28.03		0.00	0.00	
14	13.01	137.69	282.18	21.70		9.88	200.81	253.08	25.61		0.00	0.00	
15	15.75	138.16	322.26	20.46		12.51	205.51	295.82	23.66		0.00	0.00	
16	18.78	139.63	364.30	19.39		15.44	210.55	340.38	22.05		0.00	0.00	
17	22.10	141.77	408.56	18.49		18.68	215.91	386.74	20.70		0.00	0.00	
18	25.69	144.14	456.00	17.75		22.23	221.45	435.19	19.58		0.00	0.00	
19	29.57	142.74	518.20	17.53		26.09	226.72	486.94	18.66		0.00	0.00	

Base valve clickers wide open

U.wo: Suspension velocity with the base valve clicker wide open and the mid-valve clickers set at position requested on the MVc tab. If you want to evaluate the effect of the mid-valve clicker on compression damping you can re-run the calculations with the MVc clicker set at the desired position, [in/sec].

Pr.wo: Fluid pressure in the rebound chamber with the base valve compression clickers wide open, [psia].

Ft.wo: Stroke averaged damping force with the base valve clickers wide open. Mid-valve clickers are at the position specified on the MVc tab. [lbf].

Ct.wo: Averaged damping coefficient integrated over specified stroke depth with the base valve compression clickers wide opened, [lbf-sec/in].

Base valve clickers closed

U.clsd: Suspension velocity with the base valve clicker closed and mid-valve set at the position requested on the MVc input tab, [in/sec].

Pr.clsd: Rebound chamber pressure with the base valve compression clickers closed, [psia].

Ft.clsd: Stroke averaged damping force with the base valve clickers closed, [lbf].

Ct.clsd: Stroke averaged damping coefficient with the base valve clickers closed, [lbf-sec/in].

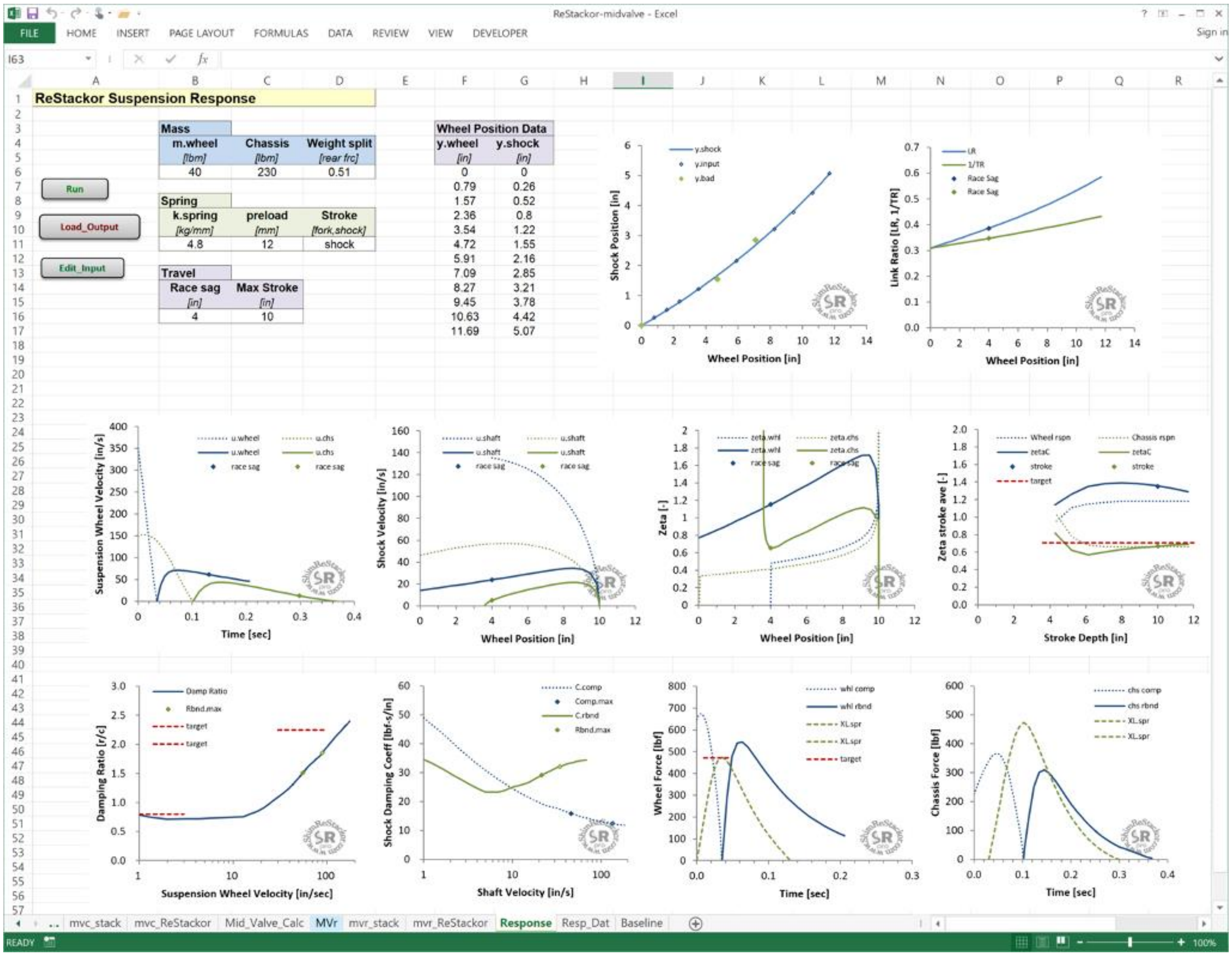
Suspension response outputs

Suspension response outputs are on the “Resp_Dat” tab of Shim ReStackor mid-valve spreadsheets. Output parameters are defined below.

Wheel and chassis bottoming

ReStackor suspension response calculations determine the wheel bump velocity required to push the compression stroke to the input specified "Max Stroke" position. The wheel bump stroke starts from the suspension normal ride height specified by the “race sag” input.

The chassis bottoming stroke assumes the bike is landing after a jump free fall and starts from full suspension extension. The calculations account for the effect of link ratio, shock gas force, spring force and damping.



ReStackor Suspension Response

Mass		
m.wheel [lbm]	Chassis [lbm]	Weight split [rear frc]
40	230	0.51

Spring		
k.spring [kg/mm]	preload [mm]	Stroke [fork,shock]
4.8	12	shock

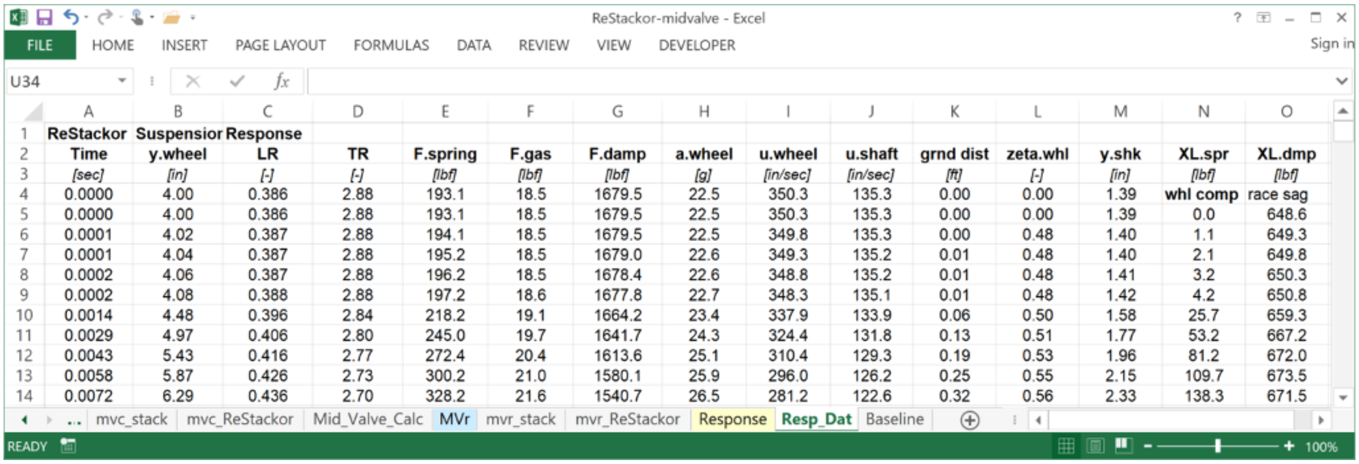
Travel	
Race sag [in]	Max Stroke [in]
4	10

Wheel Position Data	
y.wheel [in]	y.shock [in]
0	0
0.79	0.26
1.57	0.52
2.36	0.8
3.54	1.22
4.72	1.55
5.91	2.16
7.09	2.85
8.27	3.21
9.45	3.78
10.63	4.42
11.69	5.07

Wheel stroke outputs

Suspension position and velocities are tabulated on the “Resp_Dat” tab. The first output block describes the compression stroke wheel position and velocity. The second block describes the rebound stroke.

Each block is separated by a header describing the variable name and units. In each output block the first line records the value at race sag for plotting purposes.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	ReStackor	Suspensior	Response												
2	Time	y.wheel	LR	TR	F.spring	F.gas	F.damp	a.wheel	u.wheel	u.shaft	grnd dist	zeta.whl	y.shk	XL.spr	XL.dmp
3	[sec]	[in]	[-]	[-]	[lbf]	[lbf]	[lbf]	[g]	[in/sec]	[in/sec]	[ft]	[-]	[in]	[lbf]	[lbf]
4	0.0000	4.00	0.386	2.88	193.1	18.5	1679.5	22.5	350.3	135.3	0.00	0.00	1.39	whl comp	race sag
5	0.0000	4.00	0.386	2.88	193.1	18.5	1679.5	22.5	350.3	135.3	0.00	0.00	1.39	0.0	648.6
6	0.0001	4.02	0.387	2.88	194.1	18.5	1679.5	22.5	349.8	135.3	0.00	0.48	1.40	1.1	649.3
7	0.0001	4.04	0.387	2.88	195.2	18.5	1679.0	22.6	349.3	135.2	0.01	0.48	1.40	2.1	649.8
8	0.0002	4.06	0.387	2.88	196.2	18.5	1678.4	22.6	348.8	135.2	0.01	0.48	1.41	3.2	650.3
9	0.0002	4.08	0.388	2.88	197.2	18.6	1677.8	22.7	348.3	135.1	0.01	0.48	1.42	4.2	650.8
10	0.0014	4.48	0.396	2.84	218.2	19.1	1664.2	23.4	337.9	133.9	0.06	0.50	1.58	25.7	659.3
11	0.0029	4.97	0.406	2.80	245.0	19.7	1641.7	24.3	324.4	131.8	0.13	0.51	1.77	53.2	667.2
12	0.0043	5.43	0.416	2.77	272.4	20.4	1613.6	25.1	310.4	129.3	0.19	0.53	1.96	81.2	672.0
13	0.0058	5.87	0.426	2.73	300.2	21.0	1580.1	25.9	296.0	126.2	0.25	0.55	2.15	109.7	673.5
14	0.0072	6.29	0.436	2.70	328.2	21.6	1540.7	26.5	281.2	122.6	0.32	0.56	2.33	138.3	671.5

Time: Elapsed time from start of suspension stroke

y.wheel: Wheel position measured from full extension

LR: Suspension link ratio. Ratio of shock to wheel motion for an incremental change in y.wheel at the current suspension position

TR: Travel ratio. Ratio of wheel to shock travel at the current suspension position

F.spring: Spring force at wheel

F.gas: Shock gas force at wheel

F.damp: Shock damping force at shock shaft. Damping force at the wheel is given by LR*F.damp

Chassis stroke outputs

Outputs for the chassis bottoming stroke follow the wheel bump stroke and use the same output parameter definitions given above for the wheel bump stroke.

a.wheel or a.chs: Wheel or chassis acceleration at current stroke position

u.wheel or u.chs: Wheel or chassis velocity at current stroke position

u.shaft: Shock shaft velocity

zeta.whl: Suspension response zeta coefficient at current stroke position

y.shk: Shock shaft position from full extension

XL.spr: Spring plus shock gas force on wheel axel minus the race sag axel weight. The abbreviation XL stands for axel

XL.dmp: Damping force at wheel axel

Stroke averaged zeta response coefficient

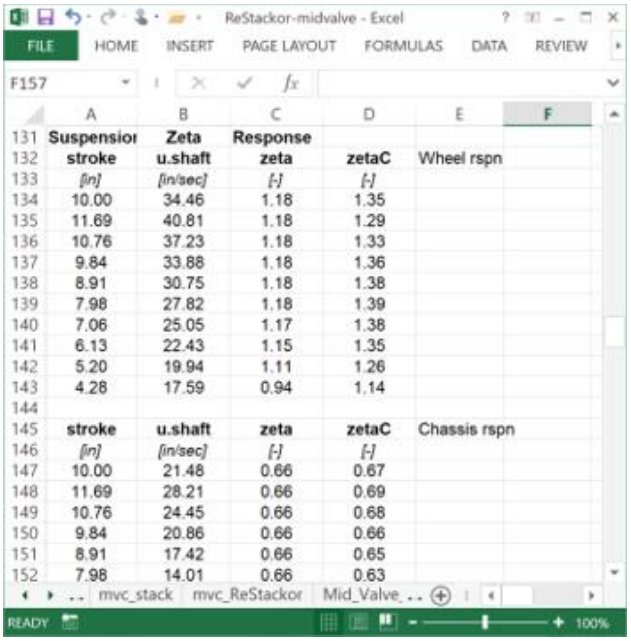
Following the wheel and chassis stroke outputs ReStackor outputs for the instantaneous and stroke averaged rebound zeta values for both the wheel and chassis are tabulated.

stroke: Maximum stroke depth measured from full extension

u.shaft: Maximum shock shaft velocity in the rebound stroke

zeta: Instantaneous rebound zeta value on return to race sag

zetaC: Stroke averaged zeta value giving same response time and final velocity as actual suspension



	A	B	C	D	E	F
131	**Suspensior**	**Zeta**	**Response**			
132	**stroke**	**u.shaft**	**zeta**	**zetaC**	Wheel rspn	
133	*[in]*	*[in/sec]*	*[-]*	*[-]*		
134	10.00	34.46	1.18	1.35		
135	11.69	40.81	1.18	1.29		
136	10.76	37.23	1.18	1.33		
137	9.84	33.88	1.18	1.36		
138	8.91	30.75	1.18	1.38		
139	7.98	27.82	1.18	1.39		
140	7.06	25.05	1.17	1.38		
141	6.13	22.43	1.15	1.35		
142	5.20	19.94	1.11	1.26		
143	4.28	17.59	0.94	1.14		
144						
145	**stroke**	**u.shaft**	**zeta**	**zetaC**	Chassis rspn	
146	*[in]*	*[in/sec]*	*[-]*	*[-]*		
147	10.00	21.48	0.66	0.67		
148	11.69	28.21	0.66	0.69		
149	10.76	24.45	0.66	0.68		
150	9.84	20.86	0.66	0.66		
151	8.91	17.42	0.66	0.65		
152	7.98	14.01	0.66	0.63		

Damping Force

ReStackor suspension response calculations use the computed compression damping force for the shock extracted from the "Mid_Valve_Calc" output tab and rebound damping force from the "mvr_ReStackor" output tab. Those values are echoed in the suspension response output data along with the rebound/compression damping ratio. The output parameters are defined below:

U.comp: Shock shaft compression velocity

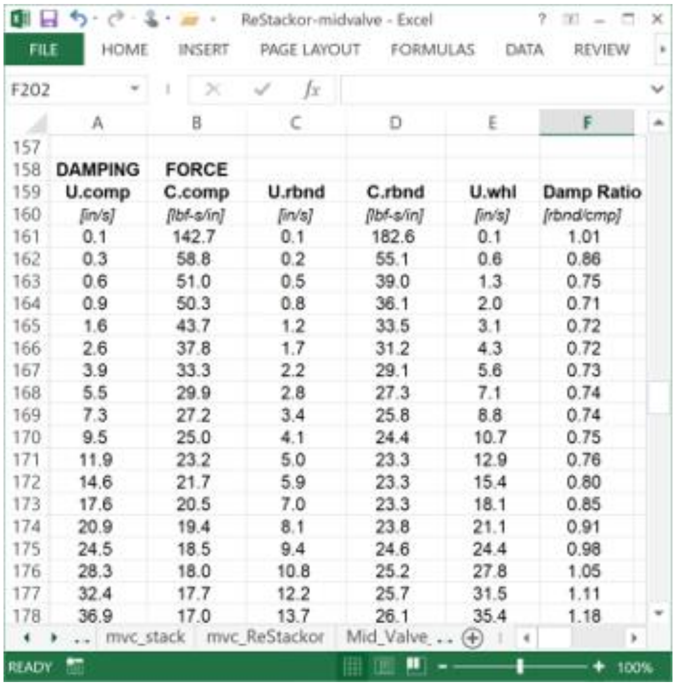
C.comp: Shock compression damping coefficient defined as the shocks compression damping force divided by shaft velocity

U.rbnd: Shock shaft rebound velocity

C.rbnd: Shocks rebound damping coefficient

U.whl: Suspension wheel velocity

Damp Ratio: Shocks rebound/compression damping ratio at the suspension wheel velocity specified by U.whl



	A	B	C	D	E	F
157						
158	**DAMPING**	**FORCE**				
159	**U.comp**	**C.comp**	**U.rbnd**	**C.rbnd**	**U.whl**	**Damp Ratio**
160	*[in/s]*	*[lbf-s/in]*	*[in/s]*	*[lbf-s/in]*	*[in/s]*	*[rbnd/cmp]*
161	0.1	142.7	0.1	182.6	0.1	1.01
162	0.3	58.8	0.2	55.1	0.6	0.86
163	0.6	51.0	0.5	39.0	1.3	0.75
164	0.9	50.3	0.8	36.1	2.0	0.71
165	1.6	43.7	1.2	33.5	3.1	0.72
166	2.6	37.8	1.7	31.2	4.3	0.72
167	3.9	33.3	2.2	29.1	5.6	0.73
168	5.5	29.9	2.8	27.3	7.1	0.74
169	7.3	27.2	3.4	25.8	8.8	0.74
170	9.5	25.0	4.1	24.4	10.7	0.75
171	11.9	23.2	5.0	23.3	12.9	0.76
172	14.6	21.7	5.9	23.3	15.4	0.80
173	17.6	20.5	7.0	23.3	18.1	0.85
174	20.9	19.4	8.1	23.8	21.1	0.91
175	24.5	18.5	9.4	24.6	24.4	0.98
176	28.3	18.0	10.8	25.2	27.8	1.05
177	32.4	17.7	12.2	25.7	31.5	1.11
178	36.9	17.0	13.7	26.1	35.4	1.18

Maximum compression and rebound stroke velocity

ReStackor suspension response calculations determine the bump impact velocity required for the suspension to achieve a full suspension stroke specified by the input link ratio data table. The “Max Damping Force” output table lists the full stroke suspension velocity.

Comp.max: Maximum shock shaft compression velocity to reach the stroke limit of the input link ratio curve. The first line specifies maximum velocities for the wheel bottoming stroke and the second line specifies the limit for the chassis bottoming stroke

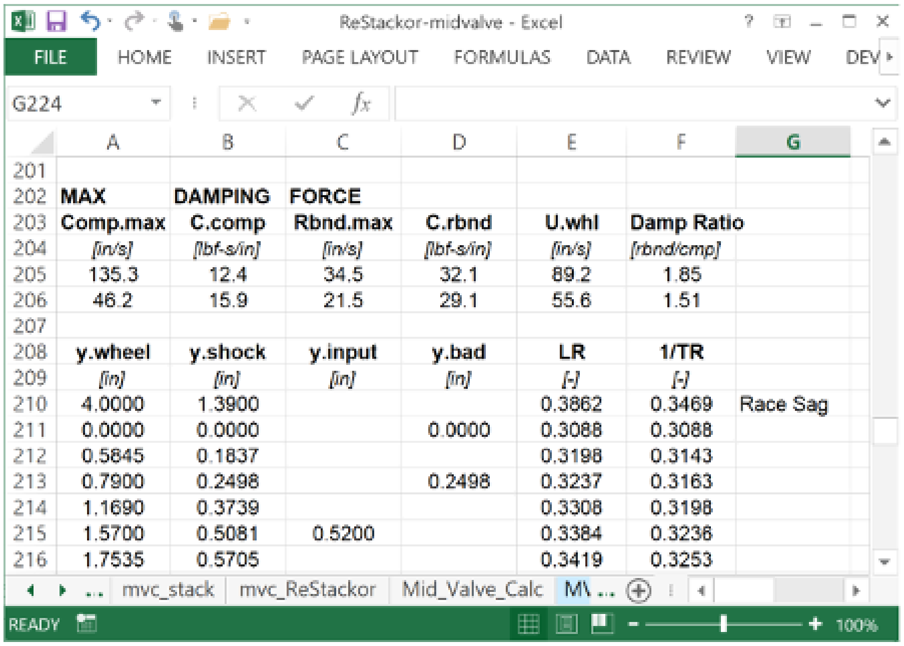
C.comp: Shock compression damping coefficient at the maximum shaft velocity

Rbnd.max: Maximum rebound shock shaft velocity for a full stroke. The first line specifies the maximum wheel stroke velocity and the second line specifies the maximum chassis rebound velocity after bottoming

C.rbnd: Shock rebound damping coefficient at the maximum shaft velocity

U.whl: Maximum rebound stroke suspension wheel velocity for the input "Max Stroke" depth. First line gives the maximum velocity during the wheel response stroke and the second line gives the chassis stroke

Damp Ratio: Rebound/compression damping ratio at the U.whl maximum rebound velocity



	A	B	C	D	E	F	G
201							
202	**MAX**	**DAMPING**	**FORCE**				
203	**Comp.max**	**C.comp**	**Rbnd.max**	**C.rbnd**	**U.whl**	**Damp Ratio**	
204	*[in/s]*	*[lbf-s/in]*	*[in/s]*	*[lbf-s/in]*	*[in/s]*	*[rbnd/cmp]*	
205	135.3	12.4	34.5	32.1	89.2	1.85	
206	46.2	15.9	21.5	29.1	55.6	1.51	
207							
208	**y.wheel**	**y.shock**	**y.input**	**y.bad**	**LR**	**1/TR**	
209	*[in]*	*[in]*	*[in]*	*[in]*	*[-]*	*[-]*	
210	4.0000	1.3900			0.3862	0.3469	Race Sag
211	0.0000	0.0000		0.0000	0.3088	0.3088	
212	0.5845	0.1837			0.3198	0.3143	
213	0.7900	0.2498		0.2498	0.3237	0.3163	
214	1.1690	0.3739			0.3308	0.3198	
215	1.5700	0.5081	0.5200		0.3384	0.3236	
216	1.7535	0.5705			0.3419	0.3253	

Suspension link ratio

The output block echoes the input wheel and shock position data used to determine the suspension link ratio along with the link ratio and travel ratio determined from the input values. Input data more than 5% off of the average curve are listed in the y.bad column and plotted as green data symbols on the link ratio plot.

y.wheel: Wheel position measured from full extension

y.shock: Shock position measured from full extension

y.input: Shock position input data

y.bad: y.input values that are more than 5% off of the average link ratio curve

Suspension response, Calculation outputs

LR: Suspension link ratio defined as the incremental change in shock position/incremental change in wheel position

1/TR: Suspension travel ratio defined as the suspension wheel position divided by the shock position. Outputs are 1/TR for plotting purposes.

Race sag spring force

Using inputs of spring rate, spring preload, shock reservoir gas force, ICS force, link ratio, chassis curb weight and rear/front weight spring ReStackor calculations determine the chassis free sag and rider weight needed to hit the target Race sag value input. Output parameters are defined below:

Free sag: Free sag necessary to support the chassis weight

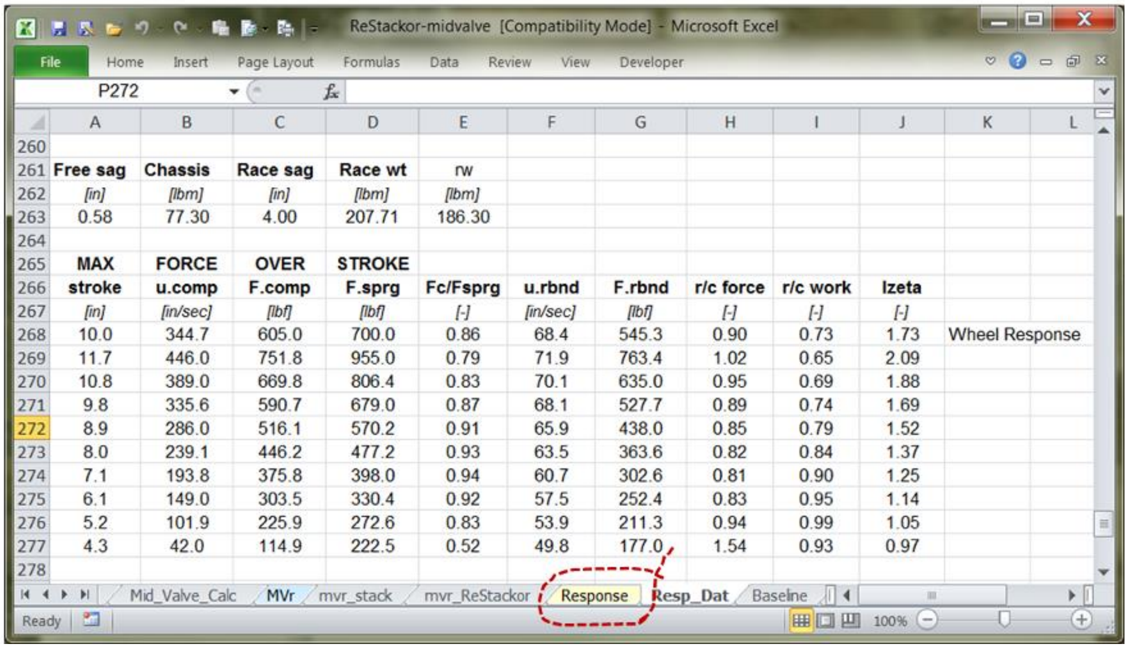
Chassis: Chassis weight on wheel based on input chassis weight and weight split

Race sag: Input value of Race sag

Race wt: Force on wheel for input value of race sag, spring rate and link ratio. If calculations are for a fork Race wt is weight on front wheel. If calculations are for a shock Race wt is the weight on the rear wheel

rw: Rider weight on foot pegs

Race sag force and Force ratios over stroke



	A	B	C	D	E	F	G	H	I	J	K	L
260												
261	Free sag	Chassis	Race sag	Race wt	rw							
262	[in]	[lbm]	[in]	[lbm]	[lbm]							
263	0.58	77.30	4.00	207.71	186.30							
264												
265	MAX	FORCE	OVER	STROKE								
266	stroke	u.comp	F.comp	F.sprg	Fc/Fsprg	u.rbnd	F.rbnd	r/c force	r/c work	Izeta		
267	[in]	[in/sec]	[lbf]	[lbf]	[-]	[in/sec]	[lbf]	[-]	[-]	[-]		
268	10.0	344.7	605.0	700.0	0.86	68.4	545.3	0.90	0.73	1.73	Wheel Response	
269	11.7	446.0	751.8	955.0	0.79	71.9	763.4	1.02	0.65	2.09		
270	10.8	389.0	669.8	806.4	0.83	70.1	635.0	0.95	0.69	1.88		
271	9.8	335.6	590.7	679.0	0.87	68.1	527.7	0.89	0.74	1.69		
272	8.9	286.0	516.1	570.2	0.91	65.9	438.0	0.85	0.79	1.52		
273	8.0	239.1	446.2	477.2	0.93	63.5	363.6	0.82	0.84	1.37		
274	7.1	193.8	375.8	398.0	0.94	60.7	302.6	0.81	0.90	1.25		
275	6.1	149.0	303.5	330.4	0.92	57.5	252.4	0.83	0.95	1.14		
276	5.2	101.9	225.9	272.6	0.83	53.9	211.3	0.94	0.99	1.05		
277	4.3	42.0	114.9	222.5	0.52	49.8	177.0	1.54	0.93	0.97		
278												

Parametric calculations evaluating rebound response zeta values over the range of stroke depths also record the maximum suspension velocity and damping force at each stroke depth. Those values along with the damping force ratio and work done are output.

Stroke: Suspension stroke depth

u.comp: Maximum suspension velocity in compression stroke

F.comp: Peak compression damping force over stroke

F.sprg: Peak spring force at stroke depth

Fc/Fsprg: Ratio of peak compression damping force to peak spring force

u.rbnd: Maximum rebound velocity at stroke depth

F.rbnd: Peak rebound force over stroke

Suspension response, Calculation outputs

r/c force: Ratio of peak compression damping force to peak rebound damping force

r/c work: Ratio of work over rebound stroke to work in compression stroke

Izeta: Instantaneous zeta value at the maximum rebound stroke velocity