Understanding Valve Spring Science and Selection, for Optimization, Performance, and Longevity

Presenter:
Jason Youd
PAC Racing Springs
Key Spring Life Factors Overview

- Spring Performance Affects
  - Maximum Engine Speed
  - Durability
  - Horsepower
  - Cost
Key Spring Life Factors Overview

- **Spring Performance Key Factors**
  - Static Stress and Design
  - Dynamic Stress and Design
  - Other Finite Components
  - It’s all in the details
Spring Design and Application

- Dynamic Design (System): 30%
- Processing: 30%
- Material: 15%
- Spring Design: 25%
Spring Design Overview Application Performance

- Material Selection (Alloy)
- Processing Selection (Recipe)
- Spring Type: Single, Beehive, Dual, Dampers, Triple
- Wire Shape (Stress per Lb.)
- Stress Range Comparisons
- Fatigue Requirements or Performance Requirements
- System Design inputs (RPM, Valve Lift Profile, Mass, other)

Higher Stress Typically equals better dynamic performance but reduces life
Spring Life Design Factors (Static)

Spring Design Factors for Stress/Life Management

• Increase Tensile Strength
  • Alloy Selection
  • Heat Treating

• Metal Improvement with Addition of Compressive Stress or reduction in Tensile Stress
  • Shot Peening
  • Stress Relieving
  • Polishing (removes stress risers)

• Spring Design Considerations
  • Wire Shape
  • Space and Application Considerations
  • Required Load (Dynamic Control)
Spring Life Design Factors (Static)

Material Tensile Strength V. Application

- Tensile Strength
- % of tensile

Typical ASTM Fastener % UTS
Spring Life Design Factors (Static)

Spring Life (Fatigue and Load)

- Life Expectancy
- Load Loss

Cycles to failure vs. Load Loss (Lbs) for:
- OEM
- LS (Street Replacement)
- Circle Track
- Drag Race
Spring Life Design Factors (Static)

Stress Range Comparisons

- Static Stress Range
- Dynamic Stress Range
- Dynamic % increased

Application Type:
- OEM
- LS (Street Replacement)
- Circle Track
- Drag Race

Dynamic Amplification %
Spring Life Dynamic Stress Factors

- Dynamic Stress Range
- Impact Force (Surge)
- Load Loss Impact (maintain dynamic robustness)
- Cooling and Heat
- Interference
- Damping (designed or external)
  - Rate Curve (progressive, dual, linear)
  - Frictional Damping (ribbon damper, interference of stacked springs, or external damper)
Spring Life Dynamic Factors

Exhaust Spring Seat Load

Coil Clash (Surge)
Bind Height and clearance critical for Energy dissipation (impact energy)
• Heat And Friction Implications
  • Increased likely hood of failures from poor oil additives. Use good quality oil and monitor changes when switching brands.
  • Consider balancing added friction and performance with failures and life expectations. Oiling is a large factor in improving spring life. (Nested Springs/Dampers)
  • Use oil as a coolant for components not just used as frictional modifier. The more captive the oil flow the more localized cooling is attained. Oiling shedding off of surface.
  • Temperature changes the modulus of materials, which changes stiffness factors. Robustness testing should be conducted to ensure heat soak performance.
Spring Life Dynamic Stress Factors

Dual LS Spring (Right Bank)
After 3 Hrs Steady Run Non-Fired Engine
(no external heat or cooling)

***Note increased thermal profile from inside spring

Notice heat at interference point (ID of nested spring)
Spring Life Dynamic Stress Factors

Beehive LS Spring (Left Bank)

After 3 Hrs Steady Run Non-Fired Engine

(no external heat or cooling)

***Note reduction in heat from inside spring
Spring Life Analysis

Excessive wear from spring to spring contact resulting in failure. Removal of shot peened surface.
Effect of Temperature on Spring Open Load

Temperature (Degrees F)

Load (lbs)
Spring Life Dynamic Performance

Effect of Temperature on Rate

Temperature (Degrees F)

Rate (lbs/inch)
Spring Life Dynamic Performance

Spring Rate Curve Types

- Linear Rate
- 2 Rate
- Progressive Rate

Height (Displacement)
Spring Rate
Spring Installed Height
Spring Open Height
Spring Life Dynamic Stress Factors

- **Controlling Spring Dynamics with Other Alternative components**

**Spring Damping Solutions**

- **Ribbon Damper**
  - Creates Heat and interference but provides good frictional damping (Located in highest stress area in spring) Known to cause spring failures from wear.

- **Steel Outside Damper**
  - Provides good interference but can be noisy and the feet break off in high stress applications.

- **Plastic Damper with Adjustable bands**
  - Provides spring wear solutions and wrapping effect from plastic, allows for more captive oil flow cooling. Tested to over 300 Million cycles used in current OEM applications.

- **Plastic Damper with Hydraulic Effect (tuned ports)**
  - Extreme cases have broken retainers from hydraulic lock-up. Oil inlet critical.
How to Measure and Identify Damping or Interference

Hysteretic Loop - is the difference vs. the static applied load (input) vs. the measured output or response (in this case interference).

We use this method to gage interference and frictional damping effects.

This method is also used in industry to determine system rigidity and compliance.

Note****

This is essentially measuring the force in compression and overlaying the force in re-bound.
Spring Life Dynamic Control (Hysteresis)

Example of Hysteresis Loop

[Graph showing a downward trend line labeled 'Spring Force']

Measured Height

Force
**Spring Life Dynamic Control (Hysteresis)**

**Hysteresis - Percent Difference of Load**

<table>
<thead>
<tr>
<th>Spring Type</th>
<th>Difference Load (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Cylindrical</td>
<td></td>
</tr>
<tr>
<td>Single Beehive</td>
<td></td>
</tr>
<tr>
<td>Dual Minimum Interference</td>
<td></td>
</tr>
<tr>
<td>Triple B&amp;C Tight C&amp;D Loose</td>
<td></td>
</tr>
<tr>
<td>Dual Tight but moves</td>
<td></td>
</tr>
<tr>
<td>Triple B&amp;C Tight C&amp;D Tight but moves</td>
<td></td>
</tr>
<tr>
<td>Triple B&amp;C Tight C&amp;D Tight</td>
<td></td>
</tr>
<tr>
<td>Dual Tight</td>
<td></td>
</tr>
<tr>
<td>Single Beehive with 1 Steel Ring OD Plastic Damper</td>
<td></td>
</tr>
<tr>
<td>Dual with Steel Damper between Outer and Inner</td>
<td></td>
</tr>
<tr>
<td>Dual with 2 Steel Ring OD Plastic Damper</td>
<td></td>
</tr>
<tr>
<td>Dual plastic damper between outer and inner</td>
<td></td>
</tr>
</tbody>
</table>

Graph showing the percentage difference of load for various spring configurations.
Spring Life Dynamic Control Alternatives

Typical Steel OD damper

Typical Steel Ribbon damper
Spring Life Dynamic Control Alternatives
Spring Life Dynamic Control Alternatives
Spring Life Dynamic Control Alternatives

Oil Ports (Exit)
Spring Life Dynamic Control Alternatives

- Engine Oil in through hydraulic action-oil captive with retainer.
- Engine Oil out through hydraulic action-sized for volume (hydraulic damping and cooling needed)

Tension Rings
(provide damping force)
Spring Life Design Factors (Static)

Thank You!

For Attending the 2012 AETC Conference

For More information please contact PAC Racing Springs
www.RacingSprings.com

Special thanks to:
Kyle Kibbey
John Keteyian