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First Contact and its Effect on Pitch of Optics

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1 Introduction

1.1 Purpose and Scope

A quick compilation of calculations of the amount a film of First Contact on a hanging optic perturbs its pitch. QUAD (monolithic, CP, and ERM), HSTS, HLTS and BSFM are considered.

1.2 Version history

8/27/12: -v1.

10/15/12: -v2. CP and ERM calculations redone with latest models, in particular, correcting the thickness (and thus pitch lever arm) for the ERM from 100 mm (CP value used in error) to 130 mm. Add wire rehang quad main chain result.

2 Background

It is desirable to leave a film of First Contact on optics as long as possible during installation and initial alignment, to protect the optics and keep them clean. However the pitch offset on a hanging optic due to the weight of the film is significant compared to the precision the pitch needs to be measured and set.

To help set requirements, the production Mathematica models of the major types of suspension, QUAD (monolithic, CP, and ERM), HLTS, HSTS, and BSFM, were used to calculate the effect of added mass on the surface of optics. In -v2, the LHO ITM that had been rehung on wires after the fibre break incident is also included.

3 Theory

The compliance of the optic in pitch can be calculated as the real part of the DC value of the transfer function from pitch torque at the optic to pitch displacement of the optic, by the Mathematica command

```
Re[calcTFf[eom2, makeinputvector[pitch3], makeoutputvector[pitch3], 0]]
```

The torque due to a mass m on the surface is

$$m \cdot g \cdot t_x / 2$$

where g is gravity and t_x is the thickness of the optic. The mass of a layer of thickness t is

$$\rho \cdot t \cdot \pi \cdot t_r^2$$

where ρ is the mass-volume density of the dried First Contact, and t_r is the optic radius (assuming First Contact applied over the whole face). The product $\rho \cdot t$ can also be considered jointly as a mass-area density.

Since it might be convenient to do further calculations in any of torque, mass and areal density, the pitch compliance w.r.t. all three were all calculated and are presented in Table 1. For ease of scaling, a hopefully representative reference area density of $1000 \text{ kg/m}^3 \cdot 0.0001 \text{ m} = 0.1 \text{ kg/m}^2$ was chosen.

Table 1

| Quantity | Monolithic | Wire Rehang | CP | ERM ¹ | BSFM | HLTS | HSTS |
|---|------------|----------------|--------|------------------|-------|-------|------|
| pitch compliance rad/(N.m) | 0.116 | 0.105 | 0.108 | 0.107 | 0.784 | 0.609 | 2.92 |
| mass compliance rad/kg, or mrad/g | 0.113 | 0.103 | 0.0532 | 0.0685 | 0.220 | 0.299 | 1.06 |
| areal density compliance mrad/(0.1 kg/m ²) | 1.03 | 0.932 | 0.484 | 0.622 | 2.36 | 1.65 | 1.88 |

4 Conclusion

The effect on pitch of a layer of fixed areal density of First Contact is moderately clustered - plus or minus a bit over a factor of two. The most sensitive is the BSFM and the least sensitive is the CP.

5 Appendix

In the PDF version of this report, printouts of the Mathematica notebooks with the calculations will be appended, to serve as documentation of the exact cases used.

¹ In -v1 of this document, a non-trivial error was noticed in the ERM case 20120601TMproductionERM (corresponding to the Matlab parameter set `^/trunk/QUAD/Common/MatlabTools/QuadModel_Production/quadopt_erm.m` r2731 in the SUS SVN): the optic thickness was 100 mm (as for the CP) rather than 130 mm. This has since been corrected, in case 20120831TMproductionERM (=r3304).

Standard calculation of QuadLite2Lateral model with First Contact calculation

■ Setup

Switches to enable loading of previously saved results instead of recalculating from scratch

```
In[1]:= useprecomputed = True; (* set to True to use saved results from precomputed subdirectory *)  
If[useprecomputed,  
    exceptdamping = False, (* False by default, True to recalculate just damping-dependent stuff*)  
    exceptdamping = True (* DON'T CHANGE *)  
];
```

```
In[3]:= loadcasefromuser["ASUS4XLLateralCaseDefn.m"];
```

```
In[4]:= modelcase
```

```
Out[4]:= {mark.barton, 20120601TMproductionTM}
```

```
In[5]:= modelcasecomment
```

```
Out[5]:= 20120601TMproductionTM, equivalent to  
         ^trunk/QUAD/Common/MatlabTools/QuadModel_Production/quadopt_fiber.m r2731 of 6/1/12
```

```
In[6]:= Calculate[Stage2]
```

■ First Contact calculation

Pitch compliance at optic in rad/(N.m)

```
In[7]:= comp = Re[calcTFf[eom2, makeinputvector[pitch3], makeoutputvector[pitch3], 0]]
```

```
Out[7]:= 0.115664
```

Effect of First Contact or other mass on surface of optic, in rad/kg or mrad/g

```
In[8]:= comp * g * tx / 2 /. constval
```

```
Out[8]:= 0.113466
```

Effect of layer of First Contact of density*thickness product 0.1kg/m² (e.g., 1000 kg/m³ times 0.0001 m), in mrad

```
In[9]:= 1000 * 0.1 * Pi * tr^2 * comp * g * tx / 2 /. constval
```

```
Out[9]:= 1.03018
```

Standard calculation of QuadLite2Lateral model with First Contact calculation

■ Setup

Switches to enable loading of previously saved results instead of recalculating from scratch

```
useprecomputed = True; (* set to True to use saved results from precomputed subdirectory *)
If[useprecomputed,
  exceptdamping = False, (* False by default, True to recalculate just damping-dependent stuff*)
  exceptdamping = True (* DON'T CHANGE *)
];
```

```
loadcasefromuser["ASUS4XLLateralCaseDefn.m"];
```

```
modelcase
```

```
{mark.barton, 20120831TMproductionTMrehang}
```

```
modelcasecomment
```

```
Corresponds to ^trunk/QUAD/Common/MatlabTools/QuadModel_Production/quadopt_wirerehang.m
r3304. Based on 20120601TMproductionTMrehang (cf r2731) with fixes to MOIs, UIM mass.
```

```
Calculate[Stage2]
```

■ First Contact calculation

Pitch compliance at optic in rad/(N.m)

```
comp = Re[calcTFf[eom2, makeinputvector[pitch3], makeoutputvector[pitch3], 0]]
```

```
0.104689
```

Effect of First Contact or other mass on surface of optic, in rad/kg or mrad/g

```
comp * g * tx / 2 /. constval
```

```
0.1027
```

Effect of layer of First Contact of density*thickness product 0.1kg/m² (e.g., 1000 kg/m³ times 0.0001 m), in mrad

```
1000 * 0.1 * Pi * tr^2 * comp * g * tx / 2 /. constval
```

```
0.932437
```

Standard calculation of QuadLite2Lateral model with First Contact calculation

■ Setup

Switches to enable loading of previously saved results instead of recalculating from scratch

```
useprecomputed = True; (* set to True to use saved results from precomputed subdirectory *)  
If[useprecomputed,  
  exceptdamping = False, (* False by default, True to recalculate just damping-dependent stuff*)  
  exceptdamping = True (* DON'T CHANGE *)  
];
```

```
loadcasefromuser["ASUS4XLLateralCaseDefn.m"];
```

```
modelcase
```

```
{mark.barton, 20120831TMproductionCP}
```

```
modelcasecomment
```

```
Corresponds to ^/trunk/QUAD/Common/MatlabTools/QuadModel_Production/quadopt_thincp.m  
r3304. Some minor MOI errors in 21020601TMproductionCP (cf. r2731) were corrected.
```

```
Calculate[Stage2]
```

■ First Contact calculation

Pitch compliance at optic in rad/(N.m)

```
comp = Re[calcTFf[eom2, makeinputvector[pitch3], makeoutputvector[pitch3], 0]]
```

```
0.108211
```

Effect of First Contact or other mass on surface of optic, in rad/kg or mrad/g

```
comp * g * tx / 2 /. constval
```

```
0.0532471
```

Effect of layer of First Contact of density*thickness product 0.1kg/m² (e.g., 1000 kg/m³ times 0.0001 m), in mrad

```
1000 * 0.1 * Pi * tr^2 * comp * g * tx / 2 /. constval
```

```
0.483754
```

Standard calculation of QuadLite2Lateral model with First Contact calculation

■ Setup

Switches to enable loading of previously saved results instead of recalculating from scratch

```
useprecomputed = True; (* set to True to use saved results from precomputed subdirectory *)
If[useprecomputed,
  exceptdamping = False, (* False by default, True to recalculate just damping-dependent stuff*)
  exceptdamping = True (* DON'T CHANGE *)
];
```

```
loadcasefromuser["ASUS4XLLateralCaseDefn.m"];
```

```
modelcase
```

```
{mark.barton, 20120831TMproductionERM}
```

```
modelcasecomment
```

```
Corresponds to ^/trunk/QUAD/Common/MatlabTools/QuadModel_Production/quadopt_erm.m r3304.
Some minor MOI errors in 21020601TMproductionERM (cf. r2731) were corrected.
```

```
Calculate[Stage2]
```

■ First Contact calculation

Pitch compliance at optic in rad/(N.m)

```
comp = Re[calcTFf[eom2, makeinputvector[pitch3], makeoutputvector[pitch3], 0]]
```

```
0.107202
```

Effect of First Contact or other mass on surface of optic, in rad/kg or mrad/g

```
comp * g * tx / 2 /. constval
```

```
0.0685046
```

Effect of layer of First Contact of density*thickness product 0.1kg/m² (e.g., 1000 kg/m³ times 0.0001 m), in mrad

```
1000 * 0.1 * Pi * tr^2 * comp * g * tx / 2 /. constval
```

```
0.62226
```

Calculation of TripleLite2 model with First Contact calculation

■ Setup

Switches to enable loading of previously saved results instead of recalculating from scratch

```
In[1]:= useprecomputed = True; (* set to True to use saved results from precomputed subdirectory *)
      If[useprecomputed,
        exceptdamping = False, (* False by default, True to recalculate just damping-dependent stuff*)
        exceptdamping = True (* DON'T CHANGE *)
      ];
```

```
In[3]:= loadcasefromuser["ASUS3L2ModelCaseDefn.m"];
```

```
In[4]:= modelcase
```

```
Out[4]:= {mark.barton, 20120120bsNW}
```

```
In[5]:= modelcasecomment
```

```
Out[5]:= Same as Jeff K's Matlab model bsfmopt_metal.m Rev 2005 of 1/19/12 (no wedge)
```

```
In[6]:= Calculate[Stage2]
```

■ First Contact calculation

Pitch compliance at optic in rad/(N.m)

```
In[7]:= comp = Re[calcTFf[eom2, makeinputvector[pitch3], makeoutputvector[pitch3], 0]]
```

```
Out[7]= 0.784482
```

Effect of First Contact or other mass on surface of optic, in rad/kg or mrad/g

```
In[8]:= comp * g * tx / 2 /. constval
```

```
Out[8]= 0.219676
```

Effect of layer of First Contact of density*thickness product 0.1kg/m² (e.g., 1000 kg/m³ times 0.0001 m), in mrad

```
In[10]:= 1000 * 0.1 * Pi * tr^2 * comp * g * tx / 2 /. constval
```

```
Out[10]= 2.36198
```

Calculation of TripleLite2 model with with First Contact calculation

■ Setup

Switches to enable loading of previously saved results instead of recalculating from scratch

```
In[1]:= useprecomputed = True; (* set to True to use saved results from precomputed subdirectory *)
      If[useprecomputed,
        exceptdamping = False, (* False by default, True to recalculate just damping-dependent stuff*)
        exceptdamping = True (* DON'T CHANGE *)
      ];
```

```
In[3]:= loadcasefromuser["ASUS3L2ModelCaseDefn.m"];
```

```
In[4]:= modelcase
```

```
Out[4]:= {mark.barton, 20120120hlts}
```

```
In[5]:= modelcasecomment
```

```
Out[5]:= Equivalent to Jeff K's hltsopt_metal.m revision 2034 of 1/24/12 for PR metal build.
```

```
In[6]:= Calculate[Stage2]
```

■ First Contact calculation

Pitch compliance at optic in rad/(N.m)

```
In[7]:= comp = Re[calcTFf[eom2, makeinputvector[pitch3], makeoutputvector[pitch3], 0]]
```

```
Out[7]= 0.608859
```

Effect of First Contact or other mass on surface of optic, in rad/kg or mrad/g

```
In[8]:= comp * g * tx / 2 /. constval
```

```
Out[8]= 0.298645
```

Effect of layer of First Contact of density*thickness product 0.1kg/m² (e.g., 1000 kg/m³ times 0.0001 m), in mrad

```
In[9]:= 1000 * 0.1 * Pi * tr^2 * comp * g * tx / 2 /. constval
```

```
Out[9]= 1.64716
```

Calculation of TripleLite2 model with with First Contact calculation

■ Setup

Switches to enable loading of previously saved results instead of recalculating from scratch

```
In[1]:= useprecomputed = True; (* set to True to use saved results from precomputed subdirectory *)
      If[useprecomputed,
        exceptdamping = False, (* False by default, True to recalculate just damping-dependent stuff*)
        exceptdamping = True (* DON'T CHANGE *)
      ];
In[3]:= loadcasefromuser["ASUS3L2ModelCaseDefn.m"];
In[4]:= modelcase
Out[4]:= {mark.barton, 20120120hsts}
In[5]:= modelcasecomment
Out[5]:= Equivalent to Jeff K's hstsopt_metal.m revision 2007 of 1/19/12.
In[6]:= Calculate[Stage2]
```

■ First Contact calculation

Pitch compliance at optic in rad/(N.m)

```
In[7]:= comp = Re[calcTFf[eom2, makeinputvector[pitch3], makeoutputvector[pitch3], 0]]
Out[7]= 2.91721
```

Effect of First Contact or other mass on surface of optic, in rad/kg or mrad/g

```
In[8]:= comp * g * tx / 2 /. constval
Out[8]= 1.06387
```

Effect of layer of First Contact of density*thickness product 0.1kg/m² (e.g., 1000 kg/m³ times 0.0001 m), in mrad

```
In[9]:= 1000 * 0.1 * Pi * tr^2 * comp * g * tx / 2 /. constval
Out[9]= 1.88001
```