Chapter 1

Demo problem: Small-amplitude non-axisymmetric oscillations of a thin-walled elastic ring

Detailed documentation to be written. Here's the already fairly well documented driver code...

```
//LIC// ====================================================================
//LIC// This file forms part of oomph-lib, the object-oriented,
//LIC// multi-physics finite-element library, available
//LIC// at http://www.oomph-lib.org.
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//LIC//
//LIC// The authors may be contacted at oomph-lib@maths.man.ac.uk.
//LIC//
//LIC//====================================================================
//Driver for small amplitude ring oscillations

//OOMPH-LIB includes
#include "generic.h"
#include "beam.h"
#include "meshes/one_d_lagrangian_mesh.h"

using namespace std;

using namespace oomph;

///////////////////////////////////////////////////////////////////////
///////////////////////////////////////////////////////////////////////
///////////////////////////////////////////////////////////////////////


//====start_of_namespace============================
/// Namespace for physical parameters
//==================================================
namespace Global_Physical_Variables
{

 /// Flag for long/short run: Default =  perform long run
 unsigned Long_run_flag=1;

 /// Flag for fixed timestep: Default = fixed timestep
 unsigned Fixed_timestep_flag=1;
```

```
 /// Boolean flag to decide if to set IC for Newmark
 /// directly or consistently : No Default
 bool Consistent_newmark_ic;

} // end of namespace

//////////////////////////////////////////////////////////////////////
//////////////////////////////////////////////////////////////////////
//////////////////////////////////////////////////////////////////////



//==start_of_problem_class============================================
/// Oscillating ring problem: Compare small-amplitude oscillations
/// against analytical solution of the linearised equations.
//====================================================================
template<class ELEMENT, class TIMESTEPPER>
class ElasticRingProblem : public Problem
{

public:

 /// Constructor: Number of elements, length of domain, flag for
 /// setting Newmark IC directly or consistently
 ElasticRingProblem(const unsigned &N, const double &L);

 /// Access function for the mesh
 OneDLagrangianMesh<ELEMENT>* mesh_pt()
  {
   return dynamic_cast<OneDLagrangianMesh<ELEMENT>*>(Problem::mesh_pt());
  }

 /// Update function is empty
 void actions_after_newton_solve() {}

 /// Update function is empty
 void actions_before_newton_solve() {}

 /// Doc solution
 void doc_solution(DocInfo& doc_info);

 /// Do unsteady run
 void unsteady_run();

private:

 /// Length of domain (in terms of the Lagrangian coordinates)
 double Length;

 /// In which element are we applying displacement control?
 /// (here only used for doc of radius)
 ELEMENT* Displ_control_elem_pt;

 /// At what local coordinate are we applying displacement control?
 Vector<double> S_displ_control;

 /// Pointer to geometric object that represents the undeformed shape
 GeomObject* Undef_geom_pt;

 /// Pointer to object that specifies the initial condition
 SolidInitialCondition* IC_pt;

 /// Trace file for recording control data
 ofstream Trace_file;
}; // end of problem class




//===start_of_constructor=============================================
/// Constructor for elastic ring problem
//====================================================================
template<class ELEMENT,class TIMESTEPPER>
ElasticRingProblem<ELEMENT,TIMESTEPPER>::ElasticRingProblem
(const unsigned& N, const double& L)
 : Length(L)
{

 //Allocate the timestepper -- This constructs the time object as well
 add_time_stepper_pt(new TIMESTEPPER());

 // Undeformed beam is an elliptical ring
 Undef_geom_pt=new Ellipse(1.0,1.0);

 //Now create the (Lagrangian!) mesh
 Problem::mesh_pt() = new OneDLagrangianMesh<ELEMENT>(
```

```
  N,L,Undef_geom_pt,Problem::time_stepper_pt());

 // Boundary condition:

 // Bottom:
 unsigned ibound=0;
 // No vertical displacement
 mesh_pt()->boundary_node_pt(ibound,0)->pin_position(1);
 // Zero slope: Pin type 1 dof for displacement direction 0
 mesh_pt()->boundary_node_pt(ibound,0)->pin_position(1,0);

 // Top:
 ibound=1;
 // No horizontal displacement
 mesh_pt()->boundary_node_pt(ibound,0)->pin_position(0);
 // Zero slope: Pin type 1 dof for displacement direction 1
 mesh_pt()->boundary_node_pt(ibound,0)->pin_position(1,1);

 // Resize vector of local coordinates for control displacement
 // (here only used to identify the point whose displacement we're
 // tracing)
 S_displ_control.resize(1);

 // Complete build of all elements so they are fully functional
 // -----------------------------------------------------------

 // Find number of elements in mesh
 unsigned Nelement = mesh_pt()->nelement();

 // Loop over the elements to set pointer to undeformed wall shape
 for(unsigned i=0;i<Nelement;i++)
  {
   // Cast to proper element type
   ELEMENT *elem_pt = dynamic_cast<ELEMENT*>(mesh_pt()->element_pt(i));

   // Assign the undeformed surface
   elem_pt->undeformed_beam_pt() = Undef_geom_pt;
  }

 // Establish control displacment: (even though no displacement
 // control is applied we still want to doc the displacement at the same point)

 // Choose element: (This is the last one)
 Displ_control_elem_pt=dynamic_cast<ELEMENT*>(
  mesh_pt()->element_pt(Nelement-1));
 // Fix/doc the displacement in the vertical (1) direction at right end of
 // the control element
 S_displ_control[0]=1.0;
 // Do equation numbering
 cout « "# of dofs " « assign_eqn_numbers() « std::endl;

 // Geometric object that specifies the initial conditions
 double eps_buckl=1.0e-2;
 double HoR=dynamic_cast<ELEMENT*>(mesh_pt()->element_pt(0))->h();
 unsigned n_buckl=2;
 unsigned imode=2;
 GeomObject* ic_geom_object_pt=
  new PseudoBucklingRing(eps_buckl,HoR,n_buckl,imode,
                         Problem::time_stepper_pt());
 // Setup object that specifies the initial conditions:
 IC_pt = new SolidInitialCondition(ic_geom_object_pt);
} // end of constructor


//===start_of_doc_solution================================================
/// Document solution
//========================================================================
template<class ELEMENT, class TIMESTEPPER>
void ElasticRingProblem<ELEMENT, TIMESTEPPER>::doc_solution(
 DocInfo& doc_info)
{

 cout « "Doc-ing step " «  doc_info.number()
      « " for time " « time_stepper_pt()->time_pt()->time() « std::endl;


 // Loop over all elements to get global kinetic and potential energy
 unsigned Nelem=mesh_pt()->nelement();
 double global_kin=0;
 double global_pot=0;
 double pot,kin;
 for (unsigned ielem=0;ielem<Nelem;ielem++)
  {
   dynamic_cast<ELEMENT*>(mesh_pt()->element_pt(ielem))->get_energy(pot,kin);
   global_kin+=kin;
   global_pot+=pot;
  }
```

```
 // Control displacement for initial condition object
 Vector<double> xi_ctrl(1);
 Vector<double> posn_ctrl(2);

 // Lagrangian coordinate of control point
 xi_ctrl[0]=Displ_control_elem_pt->interpolated_xi(S_displ_control,0);

 // Get position
 IC_pt->geom_object_pt()->position(xi_ctrl,posn_ctrl);
 // Write trace file: Time, control position, energies
 Trace_file « time_pt()->time()  « " "
            « Displ_control_elem_pt->interpolated_x(S_displ_control,1)
            « " " « global_pot  « " " « global_kin
            « " " « global_pot + global_kin
            « " " « posn_ctrl[1]
            « std::endl;


 ofstream some_file;
 char filename[100];

 // Number of plot points
 unsigned npts=5;

 // Output solution
 snprintf(filename, sizeof(filename), "%s/ring%i.dat",doc_info.directory().c_str(),
         doc_info.number());
 some_file.open(filename);
 mesh_pt()->output(some_file,npts);
 some_file.close();

 // Loop over all elements do dump out previous solutions
 unsigned nsteps=time_stepper_pt()->nprev_values();
 for (unsigned t=0;t<=nsteps;t++)
  {
   snprintf(filename, sizeof(filename), "%s/ring%i-%i.dat",doc_info.directory().c_str(),
           doc_info.number(),t);
   some_file.open(filename);
   unsigned Nelem=mesh_pt()->nelement();
   for (unsigned ielem=0;ielem<Nelem;ielem++)
    {
     dynamic_cast<ELEMENT*>(mesh_pt()->element_pt(ielem))->
      output(t,some_file,npts);
    }
   some_file.close();
  }

 // Output for initial condition object
 snprintf(filename, sizeof(filename), "%s/ic_ring%i.dat",doc_info.directory().c_str(),
         doc_info.number());
 some_file.open(filename);

 unsigned nplot=1+(npts-1)*mesh_pt()->nelement();
 Vector<double> xi(1);
 Vector<double> posn(2);
 Vector<double> veloc(2);
 Vector<double> accel(2);

 for (unsigned iplot=0;iplot<nplot;iplot++)
  {
   xi[0]=Length/double(nplot-1)*double(iplot);

   IC_pt->geom_object_pt()->position(xi,posn);
   IC_pt->geom_object_pt()->dposition_dt(xi,1,veloc);
   IC_pt->geom_object_pt()->dposition_dt(xi,2,accel);

   some_file « posn[0] « " " « posn[1] « " "
             « xi[0] « " "
             « veloc[0] « " " « veloc[1] « " "
             « accel[0] « " " « accel[1] « " "
             « sqrt(pow(posn[0],2)+pow(posn[1],2)) « " "
             « sqrt(pow(veloc[0],2)+pow(veloc[1],2)) « " "
             « sqrt(pow(accel[0],2)+pow(accel[1],2)) « " "
             « std::endl;
  }

 some_file.close();
} // end of doc solution


//===start_of_unsteady_run=============================================
/// Solver loop to perform unsteady run
//=====================================================================
template<class ELEMENT,class TIMESTEPPER>
```

```
void ElasticRingProblem<ELEMENT,TIMESTEPPER>::unsteady_run()
{

 /// Label for output
 DocInfo doc_info;

 // Output directory
 doc_info.set_directory("RESLT");

 // Step number
 doc_info.number()=0;

 // Set up trace file
 char filename[100];
 snprintf(filename, sizeof(filename), "%s/trace_ring.dat",doc_info.directory().c_str());
 Trace_file.open(filename);

 Trace_file «  "VARIABLES=\"time\",\"R<sub>ctrl</sub>\",\"E<sub>pot</sub>\"";
 Trace_file « ",\"E<sub>kin</sub>\",\"E<sub>kin</sub>+E<sub>pot</sub>\"";
 Trace_file « ",\"<sub>exact</sub>R<sub>ctrl</sub>\""
            « std::endl;
 // Number of steps
 unsigned nstep=600;
 if (Global_Physical_Variables::Long_run_flag==0) {nstep=10;}

 // Initial timestep
 double dt=1.0;

 // Ratio for timestep reduction
 double timestep_ratio=1.0;
 if (Global_Physical_Variables::Fixed_timestep_flag==0) {timestep_ratio=0.995;}

 // Number of previous timesteps stored
 unsigned ndt=time_stepper_pt()->time_pt()->ndt();

 // Setup vector of "previous" timesteps
 Vector<double> dt_prev(ndt);
 dt_prev[0]=dt;
 for (unsigned i=1;i<ndt;i++)
  {
   dt_prev[i]=dt_prev[i-1]/timestep_ratio;
  }

 // Initialise the history of previous timesteps
 time_pt()->initialise_dt(dt_prev);

 // Initialise time
 double time0=10.0;
 time_pt()->time()=time0;

 // Setup analytical initial condition?
 if (Global_Physical_Variables::Consistent_newmark_ic)
  {
   // Note: Time has been scaled on intrinsic timescale so
   // we don't need to specify a multiplier for the inertia
   // terms (the default assignment of 1.0 is OK)
   SolidMesh::Solid_IC_problem.
    set_newmark_initial_condition_consistently(
     this,mesh_pt(),static_cast<TIMESTEPPER*>(time_stepper_pt()),IC_pt,dt);
  }
 else
  {
   SolidMesh::Solid_IC_problem.
    set_newmark_initial_condition_directly(
     this,mesh_pt(),static_cast<TIMESTEPPER*>(time_stepper_pt()),IC_pt,dt);
  }

 //Output initial data
 doc_solution(doc_info);

 // Time integration loop
 for(unsigned i=1;i<=nstep;i++)
  {
   // Solve
   unsteady_newton_solve(dt);

   // Doc solution
   doc_info.number()++;
   doc_solution(doc_info);

   // Reduce timestep
   if (time_pt()->time()<100.0) {dt=timestep_ratio*dt;}
```

```
  }

} // end of unsteady run



//===start_of_main======================================================
/// Driver for ring that performs small-amplitude oscillations
//======================================================================
int main(int argc, char* argv[])
{

 // Store command line arguments
 CommandLineArgs::setup(argc,argv);

 /// Convert command line arguments (if any) into flags:
 if (argc==2)
  {
   // Nontrivial command line input: Setup Newmark IC directly
   // (rather than consistently with PVD)
   if (atoi(argv[1])==1)
    {
     Global_Physical_Variables::Consistent_newmark_ic=true;
     cout « "Setting Newmark IC consistently" « std::endl;
    }
   else
    {
     Global_Physical_Variables::Consistent_newmark_ic=false;
     cout « "Setting Newmark IC directly" « std::endl;
    }

   cout « "Not enough command line arguments specified -- using defaults."
        « std::endl;
  } // end of 1 argument
 else if (argc==4)
  {
   cout « "Three command line arguments specified:" « std::endl;
   // Nontrivial command line input: Setup Newmark IC directly
   // (rather than consistently with PVD)
   if (atoi(argv[1])==1)
    {
     Global_Physical_Variables::Consistent_newmark_ic=true;
     cout « "Setting Newmark IC consistently" « std::endl;
    }
   else
    {
     Global_Physical_Variables::Consistent_newmark_ic=false;
     cout « "Setting Newmark IC directly" « std::endl;
    }
   // Flag for long run
   Global_Physical_Variables::Long_run_flag=atoi(argv[2]);
   // Flag for fixed timestep
   Global_Physical_Variables::Fixed_timestep_flag=atoi(argv[3]);
  } // end of 3 arguments
 else
  {
   std::string error_message =
    "Wrong number of command line arguments. Specify one or three.\n";
   error_message += "Arg1: Long_run_flag [0/1]\n";
   error_message += "Arg2: Impulsive_start_flag [0/1]\n";
   error_message += "Arg3: Restart_flag [restart_file] (optional)\n";

   throw OomphLibError(error_message,
                       OOMPH_CURRENT_FUNCTION,
                       OOMPH_EXCEPTION_LOCATION);
  } // too many arguments
 cout « "Setting Newmark IC consistently: "
      «  Global_Physical_Variables::Consistent_newmark_ic « std::endl;
 cout « "Long run flag: "
      «  Global_Physical_Variables::Long_run_flag « std::endl;
 cout « "Fixed timestep flag: "
      «  Global_Physical_Variables::Fixed_timestep_flag « std::endl;

 //Length of domain
 double L = MathematicalConstants::Pi/2.0;

 // Number of elements
 unsigned nelem = 13;

 //Set up the problem
 ElasticRingProblem<HermiteBeamElement,Newmark<3> >
  problem(nelem,L);

 // Do unsteady run
```

```
problem.unsteady_run();

} // end of main
```

1.1 PDF file

A pdf version of this document is available. \