

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.
//LIC//
//LIC// Copyright (C) 2006-2022 Matthias Heil and Andrew Hazel
//LIC//
//LIC// This library is free software; you can redistribute it and/or
//LIC// modify it under the terms of the GNU Lesser General Public
//LIC// License as published by the Free Software Foundation; either
//LIC// version 2.1 of the License, or (at your option) any later version.
//LIC//
//LIC// This library is distributed in the hope that it will be useful,
//LIC// but WITHOUT ANY WARRANTY; without even the implied warranty of
//LIC// MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU
//LIC// Lesser General Public License for more details.
//LIC//
//LIC// You should have received a copy of the GNU Lesser General Public
//LIC// License along with this library; if not, write to the Free Software
//LIC// Foundation, Inc., 51 Franklin Street, Fifth Floor, Boston, MA
//LIC// 02110-1301 USA.
//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 displacement: (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
sprintf(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++)
{
    sprintf(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
sprintf(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];
    sprintf(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 nelelem = 13;

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

    // Do unsteady run

```

```
problem.unsteady_run();  
} // end of main
```

1.1 PDF file

A [pdf version](#) of this document is available.