

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

```
//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//=====
```

```
//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;
```

```
/////////////////////////////////////  
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```

```
//====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;
```

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

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

```
} // end of namespace
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////////////////////////////////////

//==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:

    /// \short 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() {}

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    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;

    /// \short 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;

    /// \short 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

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// -----
// 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 TIMESTEPER>
void ElasticRingProblem<ELEMENT, TIMESTEPER>::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);

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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 TIMESTEPER>
void ElasticRingProblem<ELEMENT,TIMESTEPER>::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 (GlobalPhysicalVariables::Long_run_flag==0) {nstep=10;}
    // Initial timestep
    double dt=1.0;
    // Ratio for timestep reduction
    double timestep_ratio=1.0;
    if (GlobalPhysicalVariables::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;
    }
}

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    }
    // 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
    {

```

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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 nele = 13;
//Set up the problem
ElasticRingProblem<HermiteBeamElement,Newmark<3> >
    problem(nele,L);
// Do unsteady run
problem.unsteady_run();
} // end of main

```

1.1 PDF file

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