Available online at www.elixirpublishers.com (Elixir International Journal)

Computer Science and Engineering

Elixir Comp. Sci. & Engg. 43 (2012) 6599-6601

ISSN: 2229-712X

Finite element model for a viscous incompressible fluid flow

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ARTICLE INFO

Article history:
Received: 26 December 2011;
Received in revised form:
22 January 2012;
Accepted: 2 February 2012;

Keywords
Finite element model,
Viscous incompressible fluid flow,
Pressure,
Velocity fields,
Penalty parameter.

ABSTRACT
In this paper, finite element model for flow of a viscous lubricant in a slider bearing is considered as a problem. For this problem, two different types of finite element models have been presented which are the velocity-pressure finite element model, with (u,v,P) as the primary nodal degrees of freedom and the penalty finite element model with (u,v) as the primary nodal degrees of freedom. Quadrilateral elements are used since they are more reliable for pressure as well as for velocity fields in the penalty finite element model.

Introduction

Problem Statement

Flow of a viscous lubricant in a slider bearing; the slider (or slipper) bearing consists of a short sliding pad moving at a velocity $u=U_o$ relative to a stationary pad inclined at a small angle with respect to the stationary pad and the small gap between the two gaps is filled with a lubricant (which is given in figure 1). Since the ends of the bearing are generally open, the pressure Po there is atmospheric. If the upper pad is parallel to the base plate, the pressure everywhere in the gap must be atmospheric (because dP/dx is a constant for flow between parallel plates) and the bearing cannot support any transverse load. If the upper pad is inclined to the base pad, a pressure distribution (in general, a function of x and y) is set up in the gap. For large values of U_o, the pressure generated can be of sufficient magnitude to support heavy loads normal to the base pad.

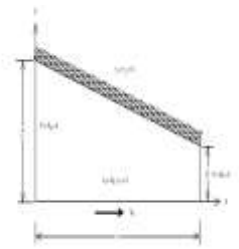

Figure 1. The geometry and boundary conditions of a slider bearing

Input data of the problem for various penalty parameters in 8x8 and 16x8 meshes are given. The necessary equation and data are as follows;

$$\frac{dP}{dx} = \mu \frac{\partial^2 u}{\partial y^2} \qquad u = u(x, y) \qquad (1)$$

$$h_1 = 2h_2 = 8x10^{-4}\ ft$$

$$L = 0.36\ ft$$

$$\mu = 8x10^{-4}\ lb/ft^2$$

$$V_0 = 30$$

Initial Condition:

At x = 0 P = 0 and at x = 0.36 P = 0

At y = 0 Ux = 30 Uy = 0 and at upper boundary Ux = 0 Uy = 0

By using these data and equation (1), viscous flow problem is solved by using an 8x8 mesh of 4 node quadrilateral elements and 16x8 (16 in x direction) elements. The effects of the various penalty parameters (such as $10^{2,}$ 10^3, 10^4, 10^5, 106, and 1011) on the velocity and pressure fields are also investigated. A program written in FORTRAN is used.

Modeling Considerations

To solve this problem by finite element method, 8x8 mesh of 4 node quadrilateral elements and 16x8 (16 in x direction) elements are employed. For these meshes, nodes numbering of the system are given in figure 2 and 3, respectively.

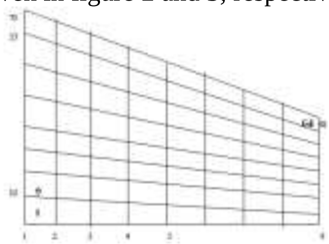

Figure 2.Finite element model for 8x8 meshes of linear quadrilateral elements

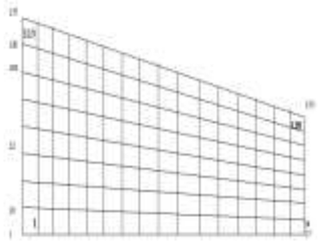

Figure 3.Finite element model for 16x8 meshes of linear quadrilateral elements

Finite Element Solution of the problem

It should be pointed out that the assumption concerning the pressure not being a function of y is not necessary in the finite

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element analysis. First, a mesh of 8x8 linear quadrilateral elements is used to analyze the problem. The boundary conditions are given in Figure 1. Finally to obtain more accurate solutions, a graded mesh of 128 linear quadrilateral elements is employed.

Solution of the problem for 8x8 mesh

Influence of the penalty parameter on the variation of the pressure and velocity values along the length of the slider bearing can be illustrated in the following figures:

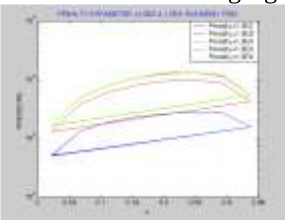

Figure 4. The comparison of results with respect to pressure values for penalty parameters such as $10^{2,}$ 10^{3}, 10^{4}, 10^{5} , 10^{6}

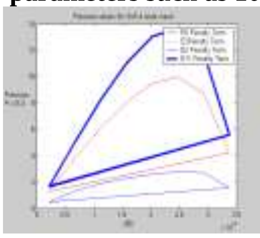

Figure 5. The comparison of results with respect to pressure values for penalty parameters such as $10^{2,}$ 10^{3}, 10^{5}, 10^{11}.

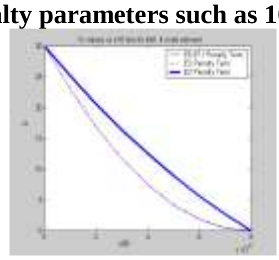

Figure 6. The comparison of results with respect to velocity values for penalty parameters such as $10^{2,}$ 10^{3}, 10^{5}-10^{11}.

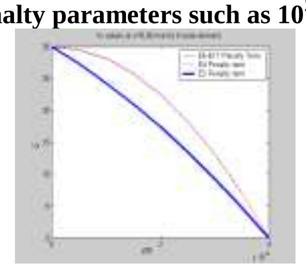

Figure 7. The comparison of results with respect to velocity values for penalty parameters such as $10^{2,}$ 10^{4}, 10^{5}-10^{11}.

Solution of the problem for 16x8 mesh

Influence of the penalty parameter on the variation of the pressure and velocity values along the length of the slider bearing can be illustrated in the following figures:

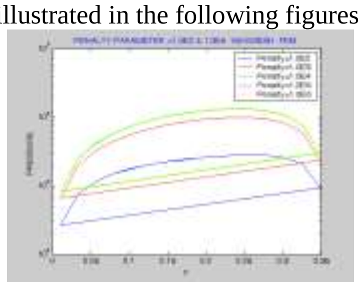

Figure 8. The comparison of results with respect to pressure values for penalty parameters such as $10^{2,}$ 10^{3}, 10^{4}, 10^{5}, and 10^{6}

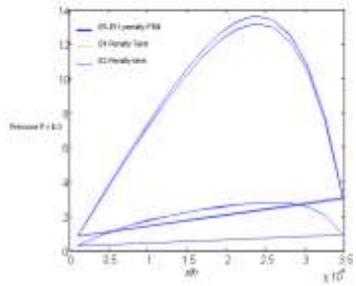

Figure 9. The comparison of results with respect to pressure values for penalty parameters such as $10^{2,}$ 10^{4}, 10^{5}-10^{11}.

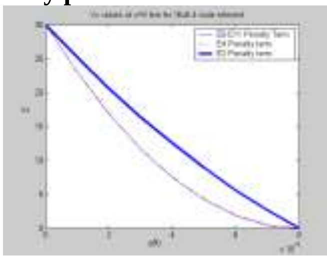

Figure 10. The comparison of results with respect to velocity values for penalty parameters such as $10^{2,}$ 10^{4}, 10^{5}- 10^{11}.

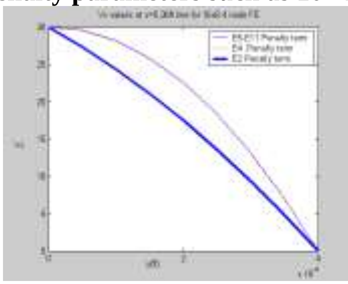

Figure 11. The comparison of results with respect to velocity values for penalty parameters such as $10^{2,}$ 10^{4}, 10^{5}-10^{11}.

Comparison of the results between 8x8 and 16x8 meshes for penalty parameter 10^{5}

Influence of the penalty parameter 10^{5} on the variation of the pressure and velocity values along the length of the slider bearing in order to compare the results between 8x8 and 16x8 meshes, can be illustrated in the following figures:

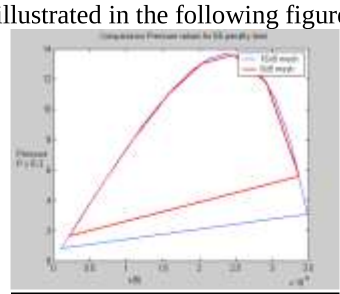

Figure 12. The comparison of results with respect to pressure values for 16x8 and 8x8 mesh element with penalty parameter 10^{5}

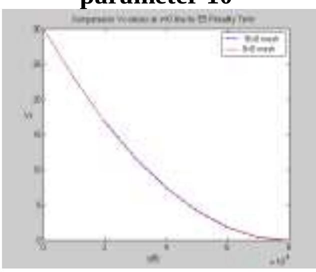

Figure 13. The comparison of results with respect to velocity values for 16x8 and 8x8 mesh element with penalty parameter 10^{5}

Results and Conclusions

Different penalty factor shows that when the penalty factor increases oscillation has higher amplitude than the lower one. Different values for penalty parameter are examined to investigate the effect on the solution results. The sensitivity of results is investigated.

In conclusion, it is clearly seen from figures and results that if penalty parameter is chosen in range between 10^5-10^{11} give same results. Therefore it can be said that if the penalty parameter is between 10^5-10^{11}, better approximation is obtained. In addition it can be said that there is a slight difference in between 8x8 and 16x8 meshes in V_x values. However for pressure values the difference is higher.

Finally finite element model 16x8 gives better approximation in between penalty parameter range 10^5-10^{11}. By increasing number of mesh elements, it is obvious that better approximations which are close to exact solution can be obtained.

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