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Pressure Distribution around Spherical Distal Ball-tip in Ultrasound Angioplasty

Graham Gavin
Technological University Dublin, graham.gavin@tudublin.ie

Garrett B. McGuinness
Dublin City University

Finbar Dolan
Medtronic Vascular Ltd, Galway

See next page for additional authors

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Authors

Graham Gavin, Garrett B. McGuinness, Finbar Dolan, and M.S. J. Hashmi

PRESSURE DISTRIBUTION AROUND SPHERICAL DISTAL BALL-TIP IN ULTRASOUND ANGIOPLASTY

Graham P. Gavin (1), Garrett B. McGuinness (1), Finbar Dolan (2), M. S. J. Hashmi (1)

1. School of Mechanical and Manufacturing Engineering, Dublin City University, Ireland
2. Medtronic AVE, Galway, Ireland

INTRODUCTION

Ultrasound Angioplasty has been shown to be effective in the removal and re-canalising of blockages in arteries (Siegel RJ, 1993). By delivering therapeutic ultrasound to the blockage, via a wire waveguide to a ball-tip, the lesion or thrombus is affected by pressure waves, micro streaming, cavitation and direct contact with the oscillating ball-tip.

Most work to date has concentrated on a spherical ball-tip geometry at the distal end of the wire waveguide (Steffen, 1994 and Rosenschein, 1996). Tip displacements usually lie between 10 - 100µm (peak-to peak) and ball tip diameters between 1 - 2mm (Atar, 1999 and Yock, 1997).

The analytical solution of an oscillating sphere is given in Equation 1 and has previously been used to describe pressures in ultrasound angioplasty (Siegel, 1996).

METHODS

To simulate the interaction between the ball-tip and surrounding fluid a Finite Element Acoustic Model using fluid-solid interaction and acoustic elements was developed.

The displacement and frequency were the input loads on the solid ball tip, while outputs included maximum nodal pressures at points in the acoustic field.

From this numerical solution a comparison was performed with the analytical solution to validate the model.

EQUATIONS

Equation 1 gives the solution for the maximum pressures around an oscillating sphere in a fluid (Morse, 1981),

$$P_0 = 2\pi^2 \rho R f^2 d_0 \times \frac{R^2 \left|\cos\theta\right|}{r^2} \qquad (1)$$

P_0= Maximum Pressure at point in field at a distance r from centre of sphere and angle θ to the axial direction, ρ =fluid density, f =frequency of oscillation, d_0 =tip displacement, R =radius of sphere.

FIGURES AND TABLES

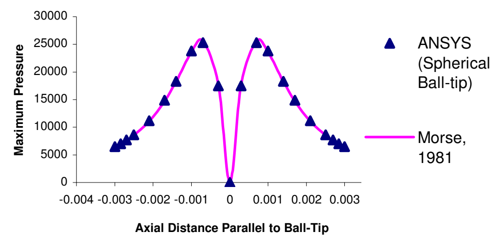

Figure 1: Maximum Pressures Distribution at 1mm axially parallel to ball-tip, f= 22.5 kHz, d_0=1.5 µm, R= 1.5mm

DISCUSSION

The correspondence between the finite element solution and the analytical solution for an oscillating sphere is shown in Figure 1. This is a plot of the maximum pressures at points axially parallel to the tip at a distance of 1mm. This location is similar to that of the arterial wall, although the presence of the wall is ignored here.

Areas of cavitation activity may be identified where the maximum pressure amplitude exceeds ambient fluid pressure. This information may aid in the design of the devices such as desirable ball-tip size, geometry and exposure time.

In future work the validated model will be used to solve the pressure distribution around more complex geometries to determine possible advantages in the use of non-spherical ball-tips.

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