OVERVIEW OF 3D PANEL METHODS

AIMS

- To give an overview 3D panel methods
- Introduce 3D point singularities
- Explain issues with surface panelling
- Explain issues with wake modelling

1 INTRODUCTION

The basic approach to the development of panel methods in 3D is essentially the same as in 2D. The methods have the same four basics stages after selecting a singularity type:

- Geometry discretisation
- Calculation of influence coefficients and influence matrix equation
- Solution of the linear set of equations
- Secondary calculations: pressures, forces, off-body velocities etc.

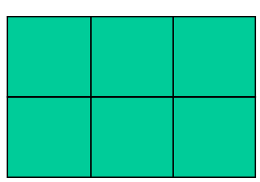
In this handout only a brief overview of some of the issues that arise in 3D is given.

2 DISTRIBUTED SINGULARITY SOLUTIONS IN 3D

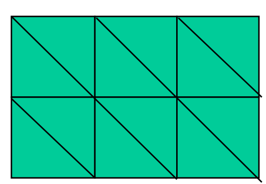
The basis of panel methods as seen in 2D was distributed singularities. The basic approach to the development of expressions for the velocities induced by a distributed singularity in 2D was to consider a small element of the "line" and evaluate the contribution of this element using the appropriate 2D point singularity formula. Integration along the line then yielded the contribution of the distributed element. In 3D a similar approach is used with the contribution of a small element of the "surface" evaluated using 3D point singularity formula. Note that these are slightly different than in 2D. Integration over the surface yields the contribution of the distributed element.

3 PANELLING ISSUES

The most common panelling strategies involve either quadrilateral or triangular panels. If a fixed number of mesh points is used to define a body then there will be less control points using quadrilateral panels than triangular panels.



12 points
6 control points



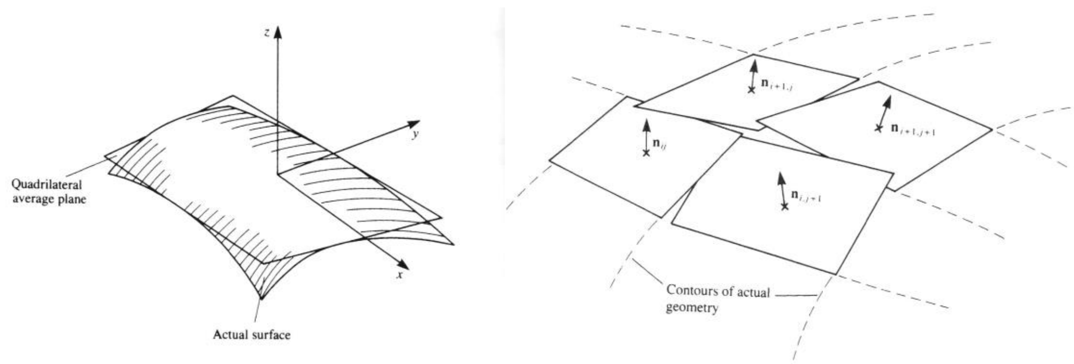
12 points
12 control points

So the matrix equation is larger for triangular panels for the <u>same mesh</u>, but the boundary condition is applied at more points so potentially it could give a more accurate solution for the <u>same mesh</u>.

A problem can occur when using quadrilateral panels because a quadrilateral panel has 4 corner points specified on the body about which the flow is being modelled and an arbitrary set of 4 points do not necessarily lie in a plane. So quadrilateral panels will in general need to be curved in order to fit the four mesh points:

- This makes the expressions for the velocities induced by the panel and the panel normal more complicated to evaluate.
- There can be gaps between panels if the curved edges of panels don't match exactly.

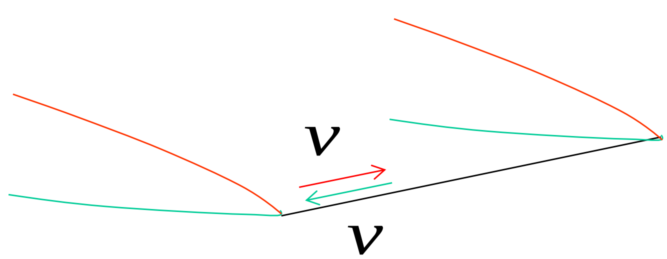
Sometimes the geometry is approximated so that flat panels can be used. This means there is some compromise on the accuracy of the representation so that mesh points are not necessarily lying on the true geometry and gaps arise between panels, which can lead to errors.



The same problems does not arise for triangular panels because 3 points always lie in a plane.

4 WAKE MODELLING

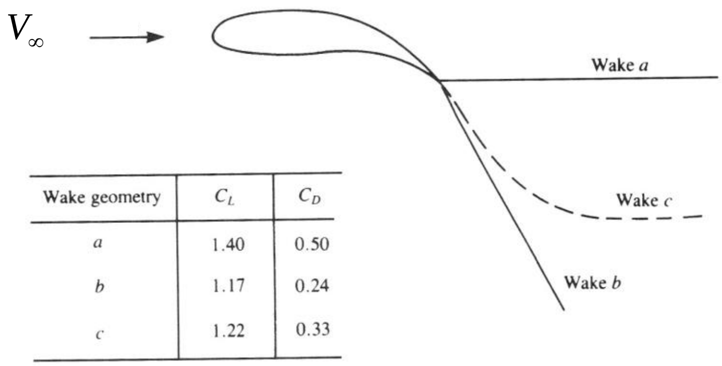
The modelling of the wake is a very important feature of a panel method and has an impact on the quality of the solution obtained. To get the correct lift need to shed the wake in the most physically realistic way. In 2D saw that the Kutta condition implies conditions on pressure and velocity, but we normally focused on the velocity when implementing it. In 3D it is more appropriate to focus on implementing it via a pressure condition to allow for spanwise flow. Equal pressure top and bottom of the aerofoil at the trailing edge implies an equal velocity magnitude, but not direction.



This allows a jump in velocity direction in the wake, which is more physically correct for wing flows (remember the 2D Kutta implies either zero velocity or identical velocities).

For steady flows, which are the only type considered in this course there is then a choice between using a fixed wake or allowing the wake to evolve during the computation. The Kutta condition means that the angle the wake leaves the trailing edge of the wing is linked to the geometry, but far downstream the wake should be aligned with the free stream. Thus a fixed flat wake will not satisfy both requirements. A fixed curved wake can be used to have the desired behaviour at the trailing edge of the wing and the far field, though the best variation in shape in between is not clear. An example of solutions using three different fixed wakes is shown in the figure below.

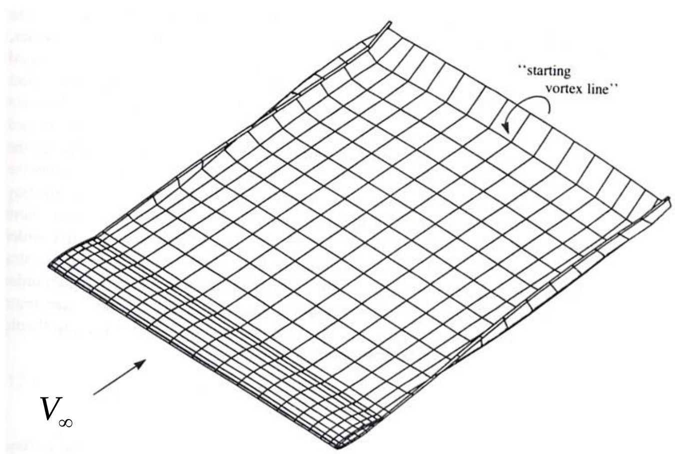
Panel solutions for AR=1.5 wing



Wake geometry	C_L	C_D
a	1.40	0.50
b	1.17	0.24
c	1.22	0.33

where wake C leads to the best solution.

However, a more physically correct approach used for steady flows is to allow the wake shape to evolve (“relax”) either from an original prescribed wake or over time from the trailing edge until there is no pressure difference across the wake. This allows not only the downstream variation in wake angle to evolve naturally, but also allows the wake edges to roll up.



REVISION OBJECTIVES

You should be able to:

- describe Discuss the issues surrounding the 3D panelling
- discuss wake modelling for 3D panel methods
- explain the limitations of panel methods and how their range of applicability may be extended