Optimal Wind Energy Extraction for Dynamic Soaring

G. Sachs

Abstract. Dynamic soaring is a flight technique for extracting energy from a horizontal wind, whose strength varies with altitude. Optimal control theory is used for dealing with the problem of minimum wind strength required for dynamic soaring. A linear shear-wind model is applied.

In the numerical investigation, results are presented for describing the characteristics of optimal dynamic soaring trajectories. Furthermore, the minimum shear-wind gradients required for dynamic soaring are determined for a wide range of parameters which are significant for the performance of sailplanes. Realistic constraints are included in the investigation.

Further topics are concerned with the energy transfer between the moving air and the sailplane and with different forms of energy-neutral trajectories.

Key Words. Dynamic soaring, flight mechanics, optimal control.

1. Introduction

Dynamic soaring is a flight method by which a sailplane extracts energy from horizontally moving air. This method differs from well-known tech-
niques like thermalling and hang gliding where upward moving air is used for feeding energy to the sailplane. Energy extraction for continuous dynamic soaring requires the horizontally moving air to be nonuniform. This means that there must be changes in the horizontal wind speed with altitude. This type of wind is called shear wind or shear flow.

The possibility of utilizing shear wind for soaring flight has been considered for quite some time (Refs. 1–15). Investigations based on energy estimations and numerical simulations provided valuable information about the wind strength necessary for dynamic soaring. Recently, modern optimization techniques have been applied to the dynamic soaring problem (Refs. 16–18). Thus, precise results are available for the minimum shear-wind strength required for dynamic soaring and for increase of the energy state of a sailplane when stronger shear-wind conditions exist.

It is the purpose of this paper to provide a further insight into the dynamic soaring problem. This concerns the optimality conditions applied, properties of optimal flight paths for dynamic soaring, and different forms of optimal energy-neutral trajectories.

2. Basic Considerations

Basically, an optimal trajectory has a form as shown in Fig. 1. Starting from point 1, the sailplane performs a turn and then a climb against the wind. In the upper part of the trajectory, it turns into the wind and descends

Fig. 1. Basic characteristics of an optimal energy-neutral trajectory (scale of sailplane increased).