WINGGRID AT TRANSONIC SPEEDS: IMPACT ON PERFORMANCE, CHALLENGES TO SOLVE

La Roche Consulting

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Abstract

Based on the reported successful fullscale testing of the Winggrid device in 1997 and tests 99 idaflieg design showing a span efficieny of 2 cf. [1], [3], [4], assessments have been made exploring application of the device on different aircraft including tentative study at higher subsonic speeds.

Motivation for these latter attempted studies is the fact, that further development of business and transport aircraft may benefit from winggrid technology due to its potential to improve aerodynamic performance, its potential to reduce span and its support of the classic Cayley type morphology already well established (in contrary to the Blended Wing Body Concept), cf [3]. It may be also interesting in terms of air traffic considerations due to its low energy wake.

The studies made will cover aerodynamic operation of the WINGGRID and design for high subsonic speeds:

If wave drag can be kept small (operation below Mach-divergence) increase of L/D for commercial type transports of 10% to 30% can be realized, equivalent at present fuel prices to 4% to 12% direct operating costs.

Assessed is design and structure of a wing with winggrid including transonic behaviour.

Trade-offs analysed are highly dependent on how the properties of a wing with winggrid is exploited, such as e.g.:

-increased wingtip stall resistance
-bigger wing volume for same total lift
-smaller span with same L/D
-increased payload per span
-increased range
-consequences of rectangular lift distribution over span

1. Preview of the results to be presented:

1.1 Summary on the WINGGRID aerodynamic operation

The device is producing multiple wakes from its blades and allows independent spanload control with no interaction from the wakes. It therefore does not have a minimum induced drag limit as given by the Munk stagger theorem cf [5].

The features of such a device have been confirmed experimentally :

- Rectangular lift distribution over span
- Multiple vortex-sheets in the WINGGRID part of span
- Span efficiencies above 2

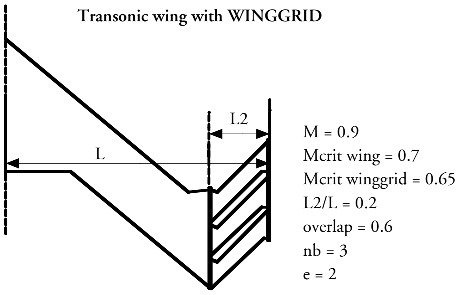
1.2 Summary of WINGGRID DESIGN

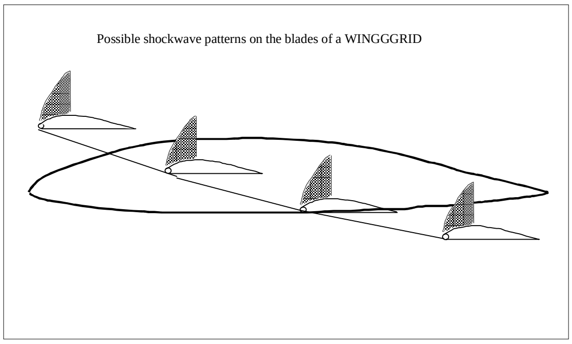
For obtaining the characteristic operation there have been identified clear design rules:

- Stagger angle: the WINGGRID device must be rotated relative to the main wing sufficiently to produce multiple vortex-sheets, if the angle of attack at low speeds exceeds a precalculated relation to the stagger angle, these vortex-sheets coalesce, the wing then starts to exhibit the aerodynamic behaviour of a normal slit wing.
- Overlap: the blades chord length must be less than the distance leading edge to leading edge of the blades in order to arrive at a clean separation of the multiple wakes produced.

- The winggrid dimension has to be stretched by a small amount for compensation of differences in the gradient of lift between main profile and WINGGRID.

Design for high subsonic speeds





Because the WINGGRID has strictly rectangular lift distribution, it lends itself to a more direct design along the lines of the infinite sheared wing model.

A complication to be worked on is adaption of infinite sheared wings to:

- Main profile ending at WINGGRID
- Endings of the blades at inner connecting plate and at outer endplate

Normal routine is considering the necessary sweep angles depending on profiles used and maximum transsonic speed allowed for.

- Because the critical Machnumber for the WINGGRID blades is lower compared to the main profiles, the sweep angle of the blades will also be different and somewhat higher.

An overlap of below 1 (ratio of blade chord to blade period) supports individual shockwave patterns on the blades of the WINGGRID.

1.3 Analysis of potential of application of WINGGRID for wings of transport aircraft

- The used precalculation procedure is presented using L/D polars with the span-efficiency as parameter.
- The available tests are evaluated and transported into this precalculation procedure.

Systematic results are summarized to fascilitate easy assessment of new wing designs in the context of operational requirements, including similar devices with multiple wakes (Spiroid).

References:

[1] La Roche U. et al..WING-GRID, Development, Qualification and Fligth Testing of a WINGGRID on a jetpowered testbed, Proceedings ICAS 98 Melbourne (Australia),

[2] http://www.rhone.ch/winggrid, the website of the WINGGRID

[3] von Tein, V.. Status and Trends on Commercial Transport Aircraft, Proceedings ICAS 98

[4] La Roche U. et al.. Induced Drag Reduction with WINGGRID-device, CEAS/DragNet European Drag Reduction Conference, June 00, Potsdam, Germany

[5] Stephen C. Smith, NASA Technical Paper 3598, Ames Research Center