Plate Lines – Mitigating Wake Turbulence Risks and Increasing Runway Throughput

So-called plate lines have been developed at the DLR Institute of Atmospheric Physics in order to shorten the lifetime of wake vortices generated by landing aircraft. Installing plate lines underneath the glide path mitigates wake vortex encounter risks and prevents go-arounds. In combination with a modern separation scheme, delays can be reduced and runway capacity can be increased.

Mitigating Wake Turbulence Risks in Ground Proximity

The highest risk to encounter wake vortices prevails in ground proximity, where the vortices cannot descend below the glide path but tend to rebound due to the interaction with the ground surface. Weak crosswinds may compensate the self-induced lateral propagation of the upwind vortex, such that it may hover over the runway directly in the flight path of the following aircraft. That's why aircraft experience wake vortex encounters time after time, even under adherence to separation standards. During final approach pilots usually initiate go-arounds, since their options to counteract the imposed rolling moment are limited at low heights above ground.

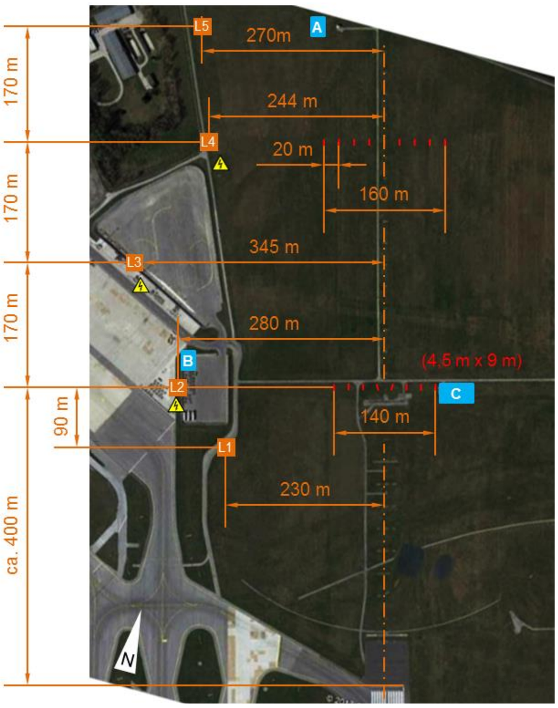

Figure 1: Positioning of plate lines (red dashes) and lidars L1 – L5 at runway 16 of Vienna airport (© Google 2017).

To mitigate the risk of wake encounters and to enhance runway capacity, so-called plate lines have been developed. Smart exploitation of vortex dynamics enables this passive, cost-effective, robust, and safe methodology: When wake vortices get close to the plate lines, strong secondary vortices are shed from the plates that actively propagate along the wake vortices and accelerate their decay [1].

Validated at Vienna Airport

The plate line effects were quantified during a measurement campaign accomplished at Vienna airport during May to November 2019. As shown in Figure 1 two experimental plate lines (red dashes) were installed at distances of about 400 m and 740 m to the threshold of runway 16. One plate line consists of 8 plates - each of 4.5 m height and 9 m length - separated by 20 m. Lidars located in measurement positions L1 – L5 were scanning in vertical planes perpendicular to the flight direction in order to measure wake vortex transport and decay.

The analysis of over 1200 wake vortex pair evolutions [1] shows that

- plate lines reduce wake vortex lifetimes as effectively as a high-turbulence regime
- a single plate line is almost as effective in promoting wake vortex decay as two plate lines
- **vortex lifetime reductions** increase with aircraft size **from 22%** for A320 **to 37%** for B772 aircraft
- plate lines **reduce circulation by 50%** for Medium follower aircraft landing behind Heavies

Ready for Permanent Installation

Figure 2: Permanent plate design consisting of four frangible aluminium lattice masts covered by nine aluminium honeycomb compound panels.

A plate line comprises eight upright plates that are positioned underneath the approach glide path. Each plate (see Figure 2) consists of four frangible aluminium lattice masts covered by nine aluminium sandwich panels with a honeycomb core. The plate design for permanent installation at an airport was developed in close collaboration with experts from Austro Control to ensure compliance with all airport-specific requirements.

Increasing Runway Throughput

Optimized aircraft separations reduce the average delay per flight which in turn will result in reduced fuel burn in the TMA. Reduced wake separations for arrivals increase the runway throughput allowing for an increased number of movements, thus higher capacity.

Table 1 features five plate line use cases. While use case I focuses on the related safety gains, use cases II to V pave the way for increased runway throughput for arrivals. The estimated runway throughputs for peak demand (listed and visualised by blue bars in line "Landings per peak hour") employ Vienna Mode S traffic data of the year 2019. The runway throughput estimated for use case V "dynamic pairwise separations" corresponds to the achievable maximum throughput, which can be realised under favourable environmental conditions, allowing minimum radar separation of 2.5 NM for all aircraft pairs.

Use Case I. Reduced wake-vortex lifetime will reduce encounter frequency corresponding to an improved **safety performance**. The reduced encounter frequency will reduce the go-around rates, leading to positive impacts on fuel efficiency, resilience and capacity.

Use Case II. The introduction of the RECAT-EU scheme or the RECAT-EU-PWS (PairWise Separation) scheme together with the installation of plate lines may advance both, **runway throughput** for arrivals (three or five additional landings per hour during peak demand) **and safety** in terms of the wake vortex encounter risks. The PWS scheme requires the installation of some controller support like the separation delivery tool LORD (Landing with Optimum Runway Delivery) developed by ECTL.

Table 1 Plate line use cases.

Use case	I. Increase Safety	II. Capacity and Safety Gains via RECAT-EU(-PWS)	III. Capacity Gains on top of RECAT-EU(-PWS)	IV. Enhance Applicability of REDSEP	V. Situational Capacity Gains via Dynamic PWS (RECAT III)
Description	• less encounters and go-arounds • install Plate Lines, no other activities needed • no capacity gains	• for airports where RECAT-EU or RECAT-EU-PWS has been or will be introduced • PWS: Plate Lines shall overcompen-sate expected add'l uncritical encounters (60%) near ground	• reduced separations identified following RECAT methods (12% - 15%) • effects along glide path to be estimated (some a/c types need adjustments)	• extend range of application (11.75%) by reducing wind threshold (V_{thr} = 6 knots) • accelerated decay of headwind provided by Plate Lines during calm winds	• reduction of separations under suitable weather conditions (e.g. DLR's WSVBS) • synergies of plate lines (at low crosswind) and wake transport (high crosswind)
Landings per peak hour	ICAO 40.5	RECAT-EU 43.5 RECAT-PWS 45.5	RECAT-EU-PL 45.6 RECAT-PWS-PL 47.2	REDSEP 41.6	MRS 50.6
Benefits / Opportunities	• avail. near term • limited effort & cost • lifetime reduction of 22%–37% depending on aircraft type • circulation reduction by 50% for MED behind HVY	• simultaneous increase of safety and capacity • reduced delays • soon available • no procedural changes and training required • encounter-risks of RECAT more than compensated	• additional capacity gains • advance maturity level in SESAR3	• capacity gains for Vienna airport supporting acceptance of REDSEP & Plate Line • can also be applied at other airports	• 85% of reduced separations limited in ground proximity • WSVBS demos at FRA and MUC airports • maximum (tactical) landing capacity (on top of RECAT-EU-PWS)
Pending		• RECAT-EU-PWS approval by EASA pending	• authority approval required	• authority approval required	• long-term goal • WX meas. & pred. • WV pred. accept.?

Use Case III. On top of use case II additional capacity gains of up to two additional landings per hour during peak demand can be made accessible by **translating accelerated wake vortex decay into reduced separations** following the methods developed for RECAT-EU [2, 3] and RECAT-EU-PWS [2]. The consideration of the effects along the glide slope is still pending and may reduce these expected capacity gains to some extent.

Use Case IV. The application range of the REDSEP method developed for airport Vienna may be extended to situations with weak winds. REDSEP can also be applied at other airports.

Use Case V. On top of use cases I to IV aircraft separation may be reduced tactically depending on the prevailing weather conditions and the resulting wake vortex behaviour. The delivery of **pairwise dynamic separations** (RECAT III) requires monitoring and prediction of weather conditions along the glide path. As separations are limited by vortex evolution in ground proximity in about 85% [4], plate lines may substantially boost the performance of the respective wake vortex advisory system.

Awards

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Maverick Award 2020: Finalist

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DLR

WVS wake vortex solutions

SORT Safely Optimised Runway Throughput

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