Mechanical Aspects of Circular Runway Aspects

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Abstract
The project „Endless Runway” was conceived during meetings of EREA (European Research Establishments in Aeronautics) association. Five of them, under leadership of Dutch NLR, formulated the proposal concerning future airport configuration. Using extended versions of current airport software and a lot of consultations with airports stakeholders and airline pilots a circular runway parameters were agreed upon for future prototype realization.

Keywords: air traffic, wind directions, runway shapes

1. Introduction
This paper contains basic assumptions and results of the „Endless Runway” Collaborative Project dedicated to one of new concepts in air transport.

Air traffic congestion, insufficient capacity at airports is the reality facing air transport today [EASA Website, www.easaonline.org]. As experts predict, air traffic shall increase twice or thrice by 2050. The sector will find itself struggling to cope with increasingly crowded skies and airports. It is also an opportunity to develop new Out-of-the-Box concepts [European Research Area, http://ec.europa.eu/research/era/index_en.htm] to boost efficiency in a vital European transport branch.

EU researchers are developing intermodal port facilities for moving people and goods at terminals – it is the goal of SAIL project. Another approach contains examination of circular runway to challenge strong winds of diverse directions. One of EC Department of Research and Innovation Calls in the Aeronautics and Air Transport topic was answered by Consortium of five EU aviation Institutes led by Dr. Henk Hesselink [Hesselink H. 2013] of Dutch NLR 1 [Hesselink H. 2013].
2. Background and assumptions of the LO AAT „Endless Runway” Project

It was dedicated to examine possible scope of application of airport with circular runway. It was assumed it could be conveyable in some localization. In the sixties of previous century such an airport was realized in Oregon, USA.

This idea was secured by several patents, but for some reasons did not find more wide application.

In 1960 US Navy Pilot James R. Conrey thought of the circular runway, having in mind the ability to land in any wind condition. In 1964 and 1965, tests were undertaken at the General Motors Desert Proving Grounds track near Mesa, Arizona, on a circular banked runway of 2560 m diameter. Successful landings and takeoffs with propeller and jet planes of varied types were made. The largest one was a C-54, which is of the size of an Airbus 319.

![Circular take-off and Landing](Time Magazine Dec. 31, 1965)

Advantages of a circular runway:
- unlimited runway available for both takeoff and landing;
- design allows unlimited flexibility in planning approach and departure corridors;
- dilution of the cross-wind problem;
- provides an inherent stable tracking feature;
- affords minimum required taxi distance and maximum runway access for the crash crews; affords optimum control tower placement;
allows optimum placement of navigation aids;
- requires a smaller total area than a comparable conventional airport;
- the centre building complex allows optimum passenger access to and departure from aircraft;
- rapid aircraft departures and arrivals possible;
- affords optimum low visibility procedures;
- compactness derived in the building complex;
- design contributes to noise abatement

In 1964 and 1965, tests were undertaken at the Proving Grounds track, which had width of 13.7 m and was banked from nearly 0° on the inside to 22° on the outside. This corresponds to equilibrium speeds varying from 0 kt to about 140 kt on the steepest portion of the runway. After a short adaptation time, pilots reported good aircraft stability during take-offs and landings and little influence of the surface wind on control forces and displacement control.

Fig.2. Banked runway
Weather aspects that have an influence on runway operations are first of all the wind speed and wind direction [ICAO Annex 14, www.2shared.com/document/NAniT8vl/ICAO-Annex-14.html]. Limitations on head wind and crosswind conditions are defined in accordance to local procedures as recommended. Landing or take-off is, in normal circumstances, precluded when crosswind component exceeds:

- 37 km/h (20 kt) for aeroplanes with reference field length >1500m except when poor runway braking action owing to an insufficient longitudinal coefficient of friction is experienced with some frequency, then component is 24 km/h (13 kt).
- 24 km/h (13 kt) for aeroplanes with reference field length between 1200m and 1500m.
- 19 km/h (10 kt) for aeroplanes with reference field length <1200m

3. Numerical simulation of air transport capacity Endless Runway variants

Activity AAT.2012.6.3-2, which encompassed this ER project, was dedicated to the Topic: Radical new concepts for air transport. Consortium was composed of researchers from 5 EU Institutes, namely:

1) NATIONAAL LUCHT- EN RUIMTEVAARTLABORATORIUM, NLR, the coordinator
2) DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT, DLR,
Main assets of a circular runway are as follows [The Endless Runway, 2012]:
- Aircraft trajectory optimization (independency from wake-vortex separation minima)
- Compact airport
- Infinite length of the runway
- Usable in any wind conditions

From the point-of-view of concept dynamics, let’s see forces equilibrium.
The centripetal force is exerted by the static friction $F$ between landing gears wheels and the runway.

![Diagram](image)

Fig. 6. Banked circular centripetal forces

The centripetal acceleration is created by the radial part of the normal force $F_C$, rather than by friction, to avoid tyres and structures wear.

The angle of summary force certainly depends on the speed $V$ and the radius $R$ of the circumference.

$$\tan \theta = \frac{V^2}{gR}$$

For ATM (Air Traffic Management) operations optimization there is a need for:

- Precise satellite navigation for final approach and landing
- Automated departure and landing sequences
- Aircraft sequencing resulting in the allocation of runway segments

Figure below presents two aircraft and the claimed temporary runway strips for each of them. Because of the different required distances the number of segments is also different. Two safety buffers should be added to cover deviations and inaccuracies and reduce the collision risk.

The key issue for airport is it capacity. We define it as the average maximum sustainable throughput (arrivals or departures) per hour at a given airport. There are following factors affecting it:

- Weather & MC designation
- Aircraft fleet mix & performance
- Controller environment & workload
- Runway occupancy times
- Overall arrival/departure split
- Number of runways in use, geometric layout, location of exits to taxiways
- State/performance of ATM system
- ATC separation requirements
- Mix and sequencing of arrivals & departures on runways
  Capacity comparative simulation in the “Flight Gear” environment was performed with two reference airports chosen:
  - Paris Charles de Gaulle as reference for a hub airport
  - Palma de Mallorca as reference for a seasonal airport

The environmental aspects of the Endless Runway have been assessed through INM (Integrated Noise Model) simulations and comparing LAQ (Local Air Quality) aspects.

4. Results and foreseen perspective

As it was identified by ACARE, the Advisory Council for Aeronautics Research in Europe, the lack of capacity at airports is a major constraint to growth in air transport today and in the following decennia (source: ACARE – Towards 2050). Current directionality of air routes results in a dependency to the wind direction and speed [Jeż M., 2006].

Fig.7. The segmented runway [Hesselink H. 2013]
Using the same approach path results in trailing aircraft having to avoid wake vortices from leading aircraft. The current activities in the scope of SESAR (Single European Sky ATM Research) might not be sufficient to obtain the capacity needed for an expected three-fold increase in air traffic, specifically under deteriorating weather conditions [EREA ATS 2050, Phase 2, 2012]. This is why a fundamentally new approach is proposed.

Airport capacity can be limited by: number and geometry of runway system, weather conditions (wind) and ATM separation requirements on the same ILS path.

Future navigation and guidance [Jeż M., 2011] should make automated operations possible. The location of all facilities (terminals, cargo area, etc.), the taxiways and stands configuration were planned in the project.

The benefits (airport footprint) were concluded and also disadvantages (impossible to extend the runway, cost of construction) of such an airport design.

In the proposed concept, the routes will consist of straight lines from 18 runway segments, where each segment can be operated in both directions. Today’s typical TMA (Terminal Manoeuvring Area) operations are defined by Standard Arrival Routes (STAR) and Standard Instrument Departure Routes (SID). These routes are predefined by a number of waypoints in relation to a specific runway. One idea of the TMA operations of the Endless Runway was based on a full free flight concept. Every aircraft can book a number of available segments at a given time and approach the airport from the direction it wants without a pre-defined route.

At the end of 20-month collaborative endeavor we were able to conclude the feasibility of prototype realization of circular airport. It should accompany
small but expanding traditional airport with one straight runway. Localization of such a new concept, challenging weather patterns deteriorating in near future, might be best at places where flat territory is available at non-expensive prices, e.g. at Ukraine stepps or Spanish meseta.

References


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European Commission, Out Of The Box Ideas about the future of air transport


Time Magazine Dec. 31, 1965