COPY Nr:

MINISTÉRIO DAS OBRAS PÚBLICAS, TRANSPORTES E COMUNICAÇÕES

GABINETE DE PREVENÇÃO E INVESTIGAÇÃO DE ACIDENTES COM AERONAVES

GPIAA

FINAL INCIDENT REPORT

AGROAR / FLYANT

Boeing B-737/300F

EC-KDJ

Madeira Airport

27th of May 2008

ESTÁ CONFORME O ORIGINAL

GPIAA

Homologo nos termos do nº 3 do artº 26º do D.L. 318/99, de 11/08/1999

2009-04-13

O Director-Adjunto,

Em substituição do Director

Fernando Ferreira dos Reis

FINAL INCIDENT REPORT Nr. 07/INCID/2008

NOTE

This report states the technical findings regarding the circumstances and probable causes which led to this incident.

In accordance with Annex 13 to the International Civil Aviation Organisation Convention, Chicago 1944, Council Directive 94/56/EC, 21st NOV 1994, and article 11th nº 3 of Decree-Law nº 318/99, 11th AUG 1999, the sole purpose of this investigation is to prevent aviation accidents. It is not the purpose of any such investigation and the associated investigation report to apportion blame or liability.

The only aim of this technical report is to collect lessons which may help to prevent future accidents.

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SYNOPSIS

On the 27th of May 2008, by 12:20 UTC[1], the Boeing B-737/300F aircraft, registration EC-KDJ, was operating a cargo flight, from Madeira (LPMA) to Lisbon (LPPT).

When the pilot set engine power for Take-Off and engaged Auto/Throttle, the aircraft started veering to the right, without nose wheel steering or differential brake control. The pilot reduced thrust, immediately, but, even so, the aircraft continued skidding until runway safety shoulder, where control was regained and the aircraft brought to runway centre line.

During that excursion out of runway, the left exterior main wheel collided with a runway edge light, which has been broken, causing the respective tire puncture.

The crew suffered no injuries and there were no other reported damages.

When GPIAA was notified the aircraft was back in the air, flying to Lisbon. The investigation process has been initiated, competent authorities notified and requested Spanish CIAIAC support, in order to get FDR transcription and other relevant information.

This report has been released in Portuguese and English Languages. In case of conflict, Portuguese version will take precedence.

[1] - All time references made in this report, unless other specified, are UTC (Universal Time Coordinated) timings. By that time of the year, in Portugal (continent and Madeira) official local time was equal to UTC time + 1 hour.

1. FACTUAL INFORMATION

1.1 History of the Flight

The aircraft, a B-737/300F, s/n 23743, Spanish registration EC-KDJ, belonging to Spanish operator “Flyant Cargo”, was operating on behave of Portuguese operator “Agroar” and performing a cargo transport flight between Madeira airport (LPMA) and Lisbon airport (LPPT).

After an heavy shower, with a light rain still falling, the aircraft started taxing towards runway 05 Take-Off position. After backtrack on runway and 180º turn on reversion pad, the aircraft lined up on threshold and, as soon as clearance was issued, the pilot advanced thrust levers, let power stabilize at 55% N1 and selected “TO/GA” on Autothrottle.

The aircraft started moving forward, but engines didn’t react symmetrically (left engine accelerating more then right one), the aircraft skidding to the right, becoming impossible for the pilot to get control, with normal means, until reaching runway safety shoulder (*picture nr. 1*), after power reduction and A/T was disconnected by the pilot flying.

Picture Nr: 1

When leaving runway, the external left main wheel hit a runway edge light and broke it.

After regaining control of the aircraft, the pilot came back to runway centreline and taxied to the ramp, exiting via taxiway “C”.

Feeling that aircraft was performing well, the captain decided to proceed the flight, reversed taxi, entered runway and lined up for take-off.

At this stage he noticed the broken runway light, in the same area the aircraft left the runway and, wondering if the light has been broken by the aircraft and if it suffered any damage, he returned to the ramp for investigation.

An external inspection revealed a scratch on outboard left main wheel tire and that wheel was changed before new departure was attempted.

1.2 Injuries

Both crew on board suffered no injuries.

1.3 Aircraft Damage

There was no reported damage to the aircraft. Only the outboard left main tire was punctured and it was changed before new departure (*picture nr. 2*).

Picture Nr. 2

1.4 Other Damage

There was no third party damage reported, but runway edge light.

1.5 Persons Involved

On board the aircraft there was, only, the flight crew, composed by two pilots (Captain and F/O) with the following references:

Reference		Captain	F/O
Personal:	Sex:	M	M
	Age:	46	41
	Nationality:	Portuguese	Spanish
	Flight License:	ATPL(A)	CPL(A)
	Validity:	22-09-2008	25-01-2012
	Ratings:	B-737; IR	B-737; IR
	Last Medical Examination:	11-03-2008	20-02-2008
	Limitations/Restrictions:	Nil	Nil
Flight Experience:	Total:	9 911:00	370:00
	Last 90 days:	111:00	18:00
	Last 30 days:	44:45	18:00
	Last week:	06:45	07:00
	Last 24 hours:	03:50	03:30

1.6 Aircraft

The aircraft, registration EC-KDJ, had a valid Airworthiness Certificate, issued by Spanish DGAC, with the following characteristics:

Reference	Airframe	Engine # 1	Engine # 2
Manufacturer:	Boeing Aircraft Comp.	CFM International	
Model:	B-737/300F	CFM56-3B2	
Serial Nr.:	23743	723102	724511
Year of Manufacture:	1988	N/A	N/A
Flight Time:	53 935 H	47 920 H	40 126 H

1.7 Meteorology

Picture Nr. 3

Visibility was good, the wind was blowing moderate from NE (12kts) and there were no low clouds or other significant phenomena, after the rain stopped (*picture nr. 3*). When take-off was attempted the runway was wet.

No turbulence, wind shear or micro bursts were reported by that time and wind direction and speed constituted any restriction for take-off.

1.8 Navigation Aids

Not applicable.

1.9 Communications

Not applicable.

1.10 Aerodrome

Located on the east side of the island, about 13km far from Funchal, Madeira airport is certified for operation of all aircraft types up to wide body planes and it has a 2781m long runway, oriented on a 050º/230º direction and 192' altitude.

The Airport is located on a plateau on the east coast of Madeira Island (*picture nr. 4*). Except for the seaside, ground raises rapidly very closed to it. This fact generates, very often, wind variation and turbulence.

Picture Nr. 4

Also severe low altitude wind shear conditions and/or micro burst are likely to be encountered. For that reason, some special procedures and crew requirements are established and may be consulted in AIP Portugal 2.20.2.

With a 0.55% average slope and grooved pavement along central runway strip, between thresholds, rain water drainage was quite efficient. Threshold areas have been left sleek and cement finished.

1.11 Flight Recorders

The aircraft was equipped with a Cockpit Voice Recorder (CVR) and a Flight Data Recorder (FDR).

The first one (CVR) had a small recording capacity, it was not removed after the occurrence, the aircraft flew to Lisbon and relevant registries were overlapped by new ones.

The second one (FDR- s/n FRE3014) continued recording and, once the aircraft returned to base, it was possible to unload the registries and get relevant take-off data.

1.12 Wreckage & Impact

Not applicable.

1.13 Medical or Pathological

Not applicable.

1.14 Fire

There was no fire.

1.15 Survival Aspects

Not applicable.

1.16 Tests & Research

1.16.1 Runway Marks

Aircraft path was well signalled on runway, after the event (*picture nr. 5*).

Picture Nr. 5

Marks of skidding started on the beginning of the runway, finishing on right runway safety shoulder, about 80m ahead. Looking for the marks on the runway we could distinguish light colours on painted surfaces and dark ones on asphalt, which may indicate that a cleaning action had occurred, where the tires acted as a broom.

An accurate inspection to the tires showed no signs of wearing or melting rubber, characteristic of dynamic or reverted rubber hydroplaning phenomenon.

1.16.2 Flight Data Recorder

1.16.2.1 General

FDR has been removed and data retrieved on the 13th of June 2008. The most important data for occurrence investigation was registered on frames 2790 to 2850, corresponding to times 12:25:10 and 12:29:10, respectfully, on day 27th of May 2008.

Data recorded before and after that period confirmed normal operation of recorder and all other aircraft systems, giving credibility to registries.

Data analysis provided the reconstruction of rejected take-off manoeuvre, with main parameters variation. Nose wheel steering and braking performance were not recorded and couldn't be considered on our study. Only engine power, heading and ruder variations were analysed. Flaps stayed in normal position, lateral acceleration was not recorded and speeds were not displayed because they didn't increase enough to be considered.

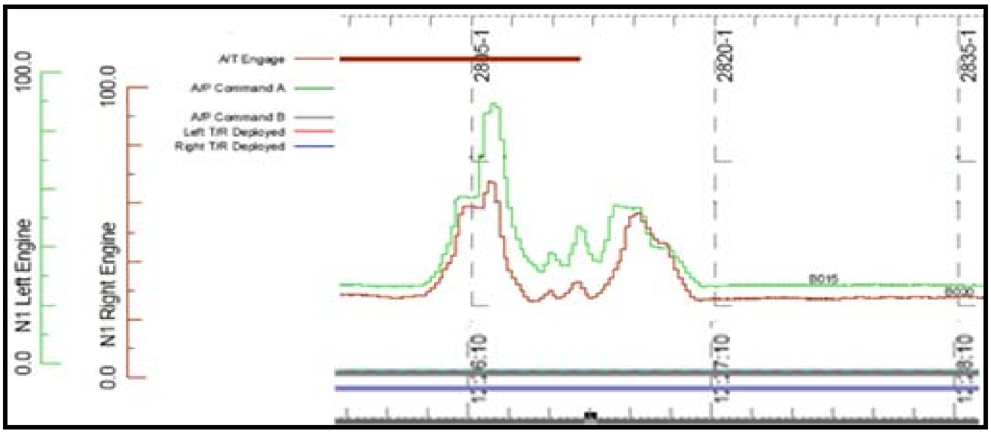
In order to increase readability of graphs, some parameters were erased from pictures presented in this report.

1.16.2.2 Engines Power

For take-off, crew elected to use Auto-Throttle (A/T) and FMC computed thrust. Picture nr: 6 represents engines power behaviour, during rejected take-off manoeuvre.

A/T has been selected after the aircraft was lined up on runway heading at time 12:21:35 (*frame 2735*) and deselected at time 12:26:40 (*frame 2812*).

When cleared for take-off (*12:26*), PF advanced throttles to 55% N1, approximately, and pressed "TO/GA" switch, activating the system for FMC computed TO power setting.



Picture Nr: 6

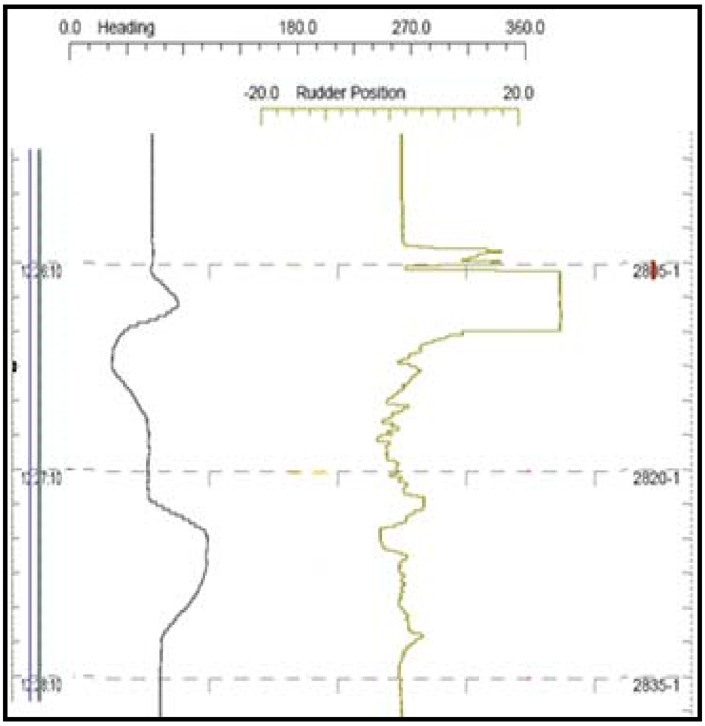
A/T didn't act symmetrically on both engines, #1 accelerating towards 88% N1, while #2 rested at 67% N1 (*picture nr. 6*).

The pilot tried to bring power to idle but he succeeded only after disconnecting A/T, being idle power established at 12:27:10 (*frame 2820*).

During all manoeuvring time, Engine's Thrust Reversers were never actuated.

1.16.2.3 Ruder Position & Aircraft Heading

Having no registry of nose wheel steering position, it's impossible to make a direct association of ruder position with heading change, as ruder is ineffective at such speeds and steering wheel takes precedence over ruder pedals steering effect.



Picture Nr: 7

As soon as take-off was initiated (*12:26:00*) there was a ruder deflection to the right (*17º*), returning to neutral and immediately set to maximum right deflection (>20º). Meanwhile aircraft heading increased from 048º to 090º (*picture nr. 7*). After those 20'' ruder remained more or less neutral but there was heading excursions from 090º to 030º, back to runway heading (045º) and to the right again (110º), before regaining heading 048º at 12:28:00 (*frame 2832*).

Despite all those heading variation, aircraft track remained more or less straight until the aircraft came to a halt.

1.16.3 Autothrottle System

The aircraft was equipped with an automatic engine power control system, operating in association with Automatic Flight Control System, providing automatic thrust control along entire flight profile from take-off to landing and moving thrust levers with separate motors for each one.

After the incident, maintenance technicians inspected the system and carried some ground tests, but no fault was detected. In order to avoid further surprises, A/T has been deactivated, waiting for further tests at company base facilities, where A/T computer was remove and sent to spare parts provider (*Futura Airways*) for further tests.

Meanwhile Futura entered a bankrupting process and access to parts became impossible, blocking any information about computer performance & capability.

1.17 Organizational & Management

Operator “AGROAR” was not prepared for direct operation of that type of aircraft. In order to fulfil its needs, operator contracted with “Flyant” the lease of the aircraft, on a wet lease base.

So, the crew was provided by “Flyant” and the operation was performed according “Flyant” approved operational procedures, as defined in its Operations Manual and AOC.

1.18 Additional Information

There’s no information regarding engines operation and no malfunction reports were referred. Nobody could provide information regarding position of PMC switches of both engines, at the time of occurrence. Data retrieved from FDR was not conclusive on that subject, as there is no registry of such parameters.

1.19 Special Investigation Techniques

No special investigation techniques were used.

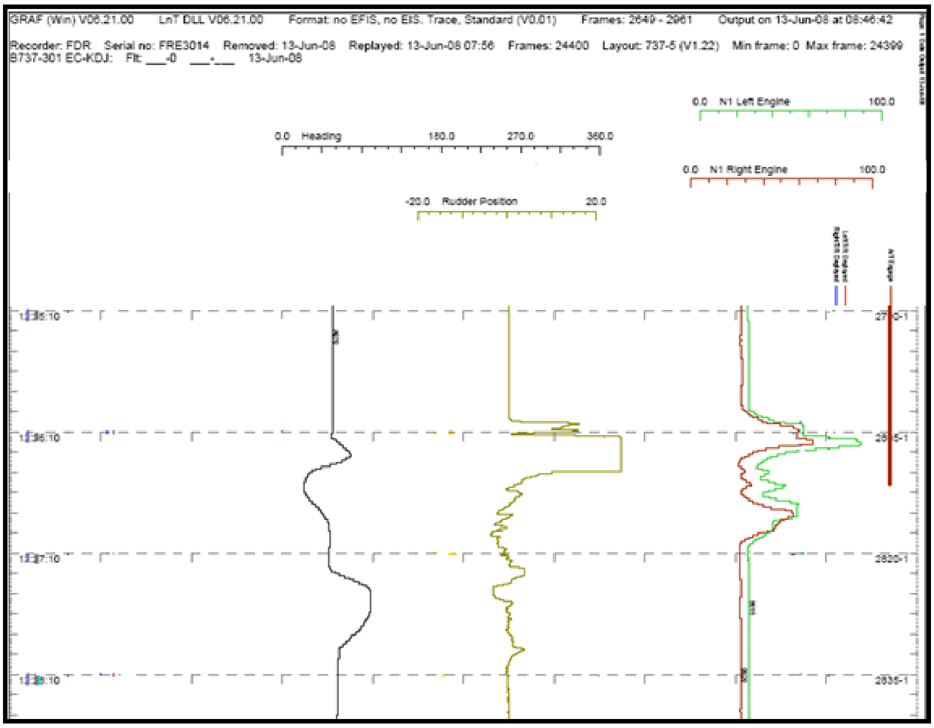
2. ANALYSIS

2.1 Take-off Sequence

Once ready for departure, crew requested necessary clearances from Madeira ATM Services and, upon receipt, started engines and taxied to runway 05 take-off position. During taxi, respective flight controls & instruments checks were performed, A/T selected and before take-off checklist completed.

After lined-up and cleared for take-off, PF set thrust levers on intermediate position, let engines spin-up to 55% N1 and pressed “TO/GA” switches. Engines acceleration was not symmetrical, engine #1 accelerating towards 88% N1 while engine #2 rested at 67% N1.

Almost simultaneously ruder deflected to the right (17º) and aircraft heading started to increase towards 090º. Pilot reduced engines thrust (20%N1) but A/T remained engaged and power increased again (40%N1) until A/T has been disconnected and thrust levers returned to “idle” (*picture nr. 8*).



Picture N: 8

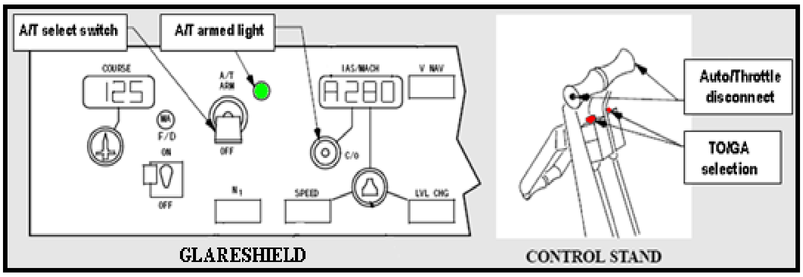
At the very moment the aircraft started moving and heading increasing, it initiated a slide that took it on a straight 30º track to the right, leaving the runway, until it stopped on runway safety shoulder. All along that track there were heading significant changes, power variation and assorted ruder actuation. Even if there is no registry of nose wheel steering actuation it is supposed to have been used by the PIC, but without any effect, as the aircraft was skidding.

2.2 Automatic Power Control System

2.2.1 Autothrottle

Boeing 737 Operations Manual states on chapter 4.20 - Autothrottle System:

> **Autothrottle System**
>
> The A/T system provides automatic thrust control from the start of takeoff through climb, cruise, descent, approach and go–around or landing. In normal operation, the FMC provides the A/T system with N1 limit values.
>
> The A/T moves the thrust levers with a separate servo motor on each thrust lever. Manually positioning the thrust levers does not cause A/T disengagement unless 10 degrees of thrust lever separation is exceeded during a dual channel approach after FLARE armed is annunciated. Following manual positioning, the A/T may reposition the thrust levers to comply with computed thrust requirements except while in the THR HLD and ARM modes.
>
> The A/T system operates properly with the PMCs ON or OFF. In either case, the A/T computer controls to the FMC N1 limits. During A/T operation, it is recommended that both PMCs be ON or both OFF, as this produces minimum thrust lever separation. A/T takeoffs may be performed with both PMCs OFF.

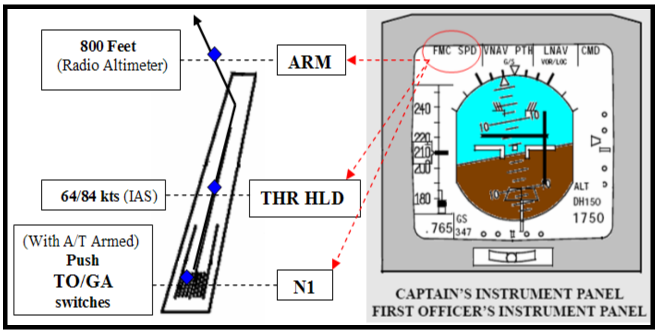


Picture Nr: 9

Pilot interface is made through A/T select switch, on glareshield, and disconnect and “TO/GA” switches, located on thrust levers (*picture nr. 9*).

A/T status is indicated on top of Electronic Attitude Director Indicator (EADI), left column (*picture nr. 10*), on Captain & F/O instrument panels.

During take-off roll, after “TO/GA” engagement, thrust levers cannot be manually repositioned before reaching 84kts (64kts for older versions) and “THR HLD” mode be displayed, or on “ARM” mode (displayed after passing 800’ radio altimeter), unless the pilot disengages A/T.

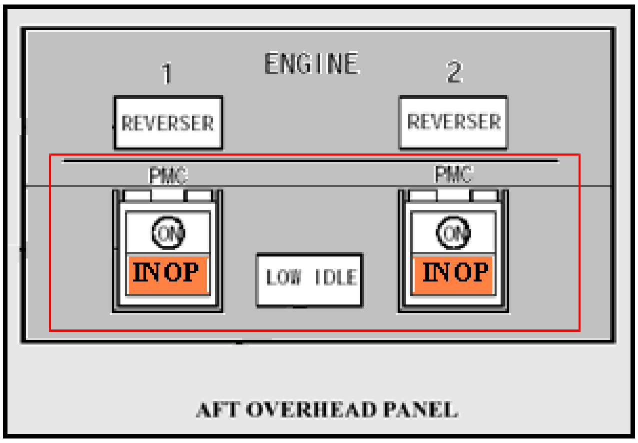


Picture Nr: 10

2.2.2 Power Management Control (PMC)

PMC is an electronic system, mounted on each engine Fuel Control Unit (FCU), operating the way expressed on Boeing 737 Operations Manual, chapter 7.20 – Power Plant:

> **Power Management Control (PMC)**
>
> The thrust control system consists of a hydromechanical MEC unit and a PMC unit mounted on each engine. The PMC is an electronic system with limited authority over the MEC.
>
> The PMC uses MEC power lever angle, N1 speed, and inlet temperature and pressure to adjust, or trim, the MEC to obtain the desired N1 speed. The PMC adjusts fuel flow as a function of thrust lever angle.
>
> The PMC provides a constant thrust climb feature once the thrust lever is set as the beginning of climb. Thus, when thrust is set for the climb, the PMC automatically maintains that thrust throughout the climb profile with no further thrust lever adjustments. If the thrust lever is repositioned, the PMC maintains the setting corresponding to the new thrust lever angle.



Picture Nr: 11

In case of malfunction of any PMC above 46%N2, or in case of PMC dis-connected, an amber “INOP” light will come on, on after overhead panel (*picture nr. 11*).

A guarded switch allows the pilot to disconnect affected PMC. Anyway, Boeing recommends switching off both PMC when using the A/T.

2.2.3 Assessment

Before take-off, EC-KDJ pilot armed A/T and, once lined up and cleared for take-off, pressed “TO/GA” switches.

There is not evidence that any PMC was switched off or malfunctioning, which could contribute to power asymmetric setting, and nobody referred the lighting of a PMC warning. Considering that PMC malfunction warning is provided only after 30 seconds of a slow N1 drift over, there was no time enough for such warning to be activated, once the pilot reduced thrust approximately fifteen seconds after power setting. As there is no registry of PMC performance on FDR, no conclusions can be made on this subject.

Regarding thrust increasing after pilot reduced thrust levers, this confirms that the aircraft never accelerated enough for the A/T change to "THR HLD" mode, thus manual reposition of thrust levers was not possible at that stage.

The most probable cause for the A/T malfunction seems to be a computer failure. That couldn't be confirmed as the computer track was lost after spares provider company closure.

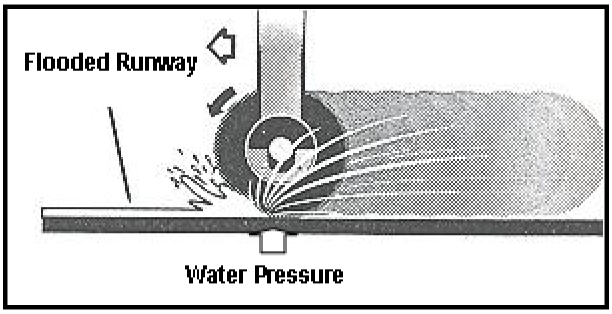
2.3 Hydroplaning

2.3.1 General

As a tire rolls on a wet runway, it is constantly squeezing the water from the tread. This squeezing action generates water pressures which can lift portions of tire off the runway, reducing the amount of friction the tire can develop. This action is called hydroplaning.

2.3.2 Dynamic Hydroplaning

At high speeds, tire forward motion tends to displace great amounts of water from the tread contact area. This displacement action can generate sufficient water pressure to lift and separate part of the tire contact area from the runway surface. This phenomenon is known as ***dynamic hydroplaning*** (*picture nr. 12*).



Picture Nr: 12

In extreme circumstances the tire may lift off the runway and ride on the wedge of water, like a water-ski. In such extreme conditions there are no braking or cornering capabilities.

In order for this kind of hydroplaning to occur some conditions must be met:

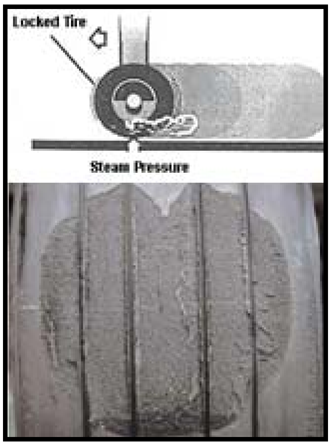
- ► Aircraft high speed;
- ► Standing water;
- ► Poor surface *macrotexture*.

If any of these conditions are not present, dynamic hydroplaning will not occur or will affect only a portion of tire footprint, with minor consequences.

EC-KDJ aircraft never reached enough speed, neither water quantity was enough (runway was wet, not flooded***) to develop this kind of hydroplaning***.

Conditions 1 and 2 were missing.

2.3.3 Reversed Rubber Hydroplaning



Picture Nr: 13

Another form of hydroplaning may occur when, even if there is some tread contact with the runway surface, the wheel is either locked or rotating slowly, with aircraft travelling at high speed. The friction produced by the skidding tire causes the tread material to become extremely hot. The resulting heat evaporates the water and generates steam in the contact area, providing additional upward pressure on the tire. The hot steam reverses the vulcanizing process and the tread rubber becomes irregular in appearance (gummy), resulting in a very low friction levels and braking capabilities (*picture nr. 13*).

Based on this characteristic it's called ***reversed rubber hydroplaning***.

This process can be initiated at any speed above 20kts and occurs only when the tire becomes locked and it skids along a very wet or icy runway for a period long enough to develop sufficient heat.

EC-KDJ aircraft had no time for heat enough to be generated and tires showed no signs of rubber vulcanization reversion process.

2.3.4 Viscous Hydroplaning

Despite these being the most common and referred categories of hydroplaning, there is another kind that is not so talked about and sometimes is mistakenly classified as dynamic hydroplaning.

It's called ***viscous hydroplaning*** and it occurs anytime there's a wet runway (*a thin film of fluid no more than 0.025mm in depth is enough*) and a normal slipperiness or water lubricating action is felt (*picture nr. 14*). The tire cannot penetrate the fluid and it rolls on top of the film. This viscous hydroplaning can occur at a much lower speed than dynamic hydroplaning, but requires a smooth or smooth-acting surface such as an oil, dust or rubber contaminated flat runway.

Picture Nr: 14

EC-KDJ aircraft didn't reach minimum speed for dynamic or reversed rubber hydroplaning. Nevertheless there were visible runway marks of skidding, which confirmed the occurrence of viscous hydroplaning, due the presence of dust on the runway smooth surface, covered by a light wet film.

3. CONCLUSIONS

3.1 Findings

Based on what has been exposed, we may conclude that:

1st The flight was programmed and performed according with operator requirements and procedures;

2nd The crew was certified to operate the aircraft and duly qualified for that runway;

3rd Aircraft documents were inside validity period, maintenance programme had been complied with, having no report of any malfunction or restriction to normal operation;

4th The moment take-off was initiated, at the very beginning of the runway (threshold marks), the runway was wet and slightly muddy;

5th When thrust levers were manually advanced, power increase was symmetrical on both engines (55%N1);

6th After "TO/GA" has been selected, A/T didn't act symmetrically on both engines, engine #1 accelerating more than engine #2;

7th As soon as A/T was engaged, the aircraft started veering to the right;

8th Pilot reduced engine power and tried to bring the aircraft to the centre line, but no flight controls, brakes or nose wheel steering effective control was possible;

9th The aircraft entered in viscous hydroplaning and left runway into right runway safety shoulder, where it stopped;

10th Runway marks confirmed a pavement very thin texture and the presence of dust on runway surface;

11th A technical inspection, by on site maintenance personnel, couldn't determine the probable cause of A/T malfunction;

12th A/T has been inhibited and the aircraft continued with flight programme, until it arrived at base, where A/T computer was changed;

13th A/T computer has been sent for investigation, but its track was lost when spares provider company went bankruptcy;

14th The aircraft suffered no damage, but a scratch on outboard left main tire;

15th There was no third party damage reported, but a broken runway side light;

16th Both pilots on board were unhurt.

3.2 Causes of the Accident

3.2.1 Primary Cause

Primary cause for this incident was the asymmetrical activity of Autothrottle system, which caused engine #1 power increase greater than engine #2, forcing the aircraft to veer to the right.

3.2.2 Contributory Factors

The following were considered as Contributory factors:

1st The presence of a light water film on runway, due recent rain;

2nd The presence of dust particles on the runway;

3rd The aircraft being on the painting marks of runway threshold;

4th The absence of grooving on that part of runway surface, with poor *macrotexture*;

Rain water, combined with dust, formed a thin mud film on top of a smooth runway, in order to create a highly slippery surface. When asymmetrical engine power forced the aircraft to veer to the right, it started skidding, entering in a viscous hydroplaning situation. Without grooving to stop the hydroplaning phenomenon, the aircraft continued skidding until reaching runway safety shoulder, which was not so smooth, where tires got contact with surface and control was regained.

4. SAFETY RECOMMENDATIONS

Considering that primary cause for this incident has been the engine's asymmetrical acceleration, once A/T was engaged for take-off, a comprehensive check should be performed on A/T system, in order to determine the faulty part;

As such investigation couldn't be completed because trace of A/T computer has been lost;

It is not appropriate to issue any recommendation regarding A/T system.

Anyway that failure wouldn't be enough for the aircraft to become uncontrolled if there was adherence enough of tires to the runway surface.

Considering that skidding was due to the presence of a thin mud film on top of threshold smooth runway surface;

Recognizing that the presence of any surface irregularity would be enough to stop skidding and regain aircraft control;

Having in mind that subsequent parts of runway surface are grooved and assure a better directional control;

Being granted by Airport Authority the regular braking coefficient testing and decontamination operations carried out;

Once it is not affordable to alter threshold surface *macrotexture*;

It is recommended

To ANAM (Madeira Airports Authority):

"*To include a note on Civil Pilot Manual (AGA 2-17A, 15) and on AIP Portugal (LPMA AD 2.20.2), calling pilot's attention for the possibility of viscous hydroplaning development, on ungrooved runway surfaces, with runway wet".* (RS Nr: 03/2009)

Lisbon, February the 09th, 2009

The Investigator In Charge,

António A. Alves