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CONCORDE ACCIDENT

Appendix to An impossible dream

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CONCORDE ACCIDENT

Nobody gathering in the large exclusive Concorde lounge before boarding Air France Concorde flight 459 in Paris, July 25th 2000, could have imagined that their flight would end in disaster within minutes after take off. Concorde had till then the reputation to be the safest working passenger airliner in the world. Passengers took either their entitled foot massage, back massage, facial or pedicure, take a last luxurious shower - surrounded with classical music - or just enjoyed the famous sandwich platter including caviar and a first glass of champagne. Concorde Boarding was another ritual; again with champagne served the moment you took the leather seat. Queue for take off, the captain explained the procedures of starting up the Rolls Royce engines and that reheats were applied during take off to reach 250 mph within 30 seconds - ahead a DC 10 started his take off roll and lost a piece of metal seconds later - Concorde was next. Experiencing Concorde's bumpy acceleration on the runway - champagne at hand - passing V_1 speed disaster struck when a wheel hit the lost piece of metal shredding a tire and a piece of rubber impacted one of the fuel tanks - leaking fuel ignited….

During the 27 years it was in service, Concorde flew only limited miles - carrying just 2.5 million passengers on some 50.000 flights and after the Paris accident Concorde was suddenly rated as the by far worst

aircraft in service worldwide. This proved soon to be a correct rating. Unknown to the passengers - but well known to the pilots - Concorde had a record of busted tires. 57 accidents involving a busted tire happened during the period 1976 to 2000, of which 12 caused serious damage to the plane, including 6 times a perforation of the fuel tank, once all the way through the wing - this time it let to fatal accident. Concorde was not safe at all but had a very long history of problems. That the accident did not happen at a much earlier moment was shear luck.

Jetliners were now booming business with the Americans dominating the market. This to great dissatisfaction of the British who had lost out with the Comet and also to the French whose aircraft industry had not yet recovered from the war. Also the Russians were waiting in the sidelines. To regain control a breakthrough technology was needed. Based on early success by the military it was 'obvious' that supersonic was the next logical step for airliners.

Swept wing concept

A German aerodynamicist - Dietrich Kuchemann - who had moved to the UK after the war delivered with his swept wing concept a technology that makes it possible to fly with full control above the speed of sound – and led ultimately to the thin-winged delta shaped design of the Concorde. UK and France signed up for the development in 1962 and the Concorde went first supersonic October 1st, 1969 - a stunning technical achievement. Soon seventy orders were booked but were just as soon cancelled, because

of essentially unforeseen international developments. The US, trailing in second position, cancelled its supersonic transport program in 1971 - Boeing, who had designed a much larger 300 passenger supersonic, decided for its 747 which had just entered service. This soon proved to be a very wise decision when the world became confronted with the oil crises in 1973. The sharp increase of fuel costs posed a huge problem to the Concorde, which has an extremely high fuel demand. At supersonic speed an Atlantic flight takes about one ton of kerosene per passenger seat versus less than a quarter ton at subsonic. As it happened, the Russian counterpart of the Concorde, the TU-144, tragically crashed at the Paris Air Show also in 1973. This made further sales of this plane impossible but meant also a mayor set back for the marketing of the Concorde. Marketing became also hindered – much more than anticipated - by public complaint about noise and became a political issue. Indeed, a loud boom sounded every morning in Kerry Ireland around 11 a.m. - often very loud and led to serious complaint. In the end only 20 Concorde's were built, six for development and 14 for commercial service. The plane began scheduled flights in 1976 – cutting short a trip from Paris to New York to just under 3.5 hours - until it was grounded after the Paris crash. After a fifteen-month Return to Service Program, Concorde was recertified and resumed service September 2001. The slump in air travel after 9/11 led to operations to be definitely ceased in 2003. Concorde made a last emotional retirement flight, with three planes landing at Heathrow November 26th, shortly after 4 p.m. ending an era of supersonic civil aviation.

The weight issue

With the Concorde aviation entered new territory because aircraft behave very different at super sonic speeds. Both design and production required technology to be stretched again to the limit. Testing did set records and so did the development cost overrun of some 600%. Forces are extreme and heat is generated by compression of air when the plane travels supersonic. Conventional aluminum was the construction material of choice but this cannot sustain more than 1270 ^{0}C because of fatigue. This restriction limited top speed to Mach 2.02 - but this is also about the 'optimum' for fuel efficiency. Engineers had to settle for turbojets because more efficient and more quit turbofans needed to be larger and heavier to give the required high trust needed for take off, transonic acceleration and supersonic cruise. The engineers focused on efficient fuel consumption with the jet cruising at supersonic cruise speed at some 60.000 ft, but this made them more inefficient for subsonic cruise and special measure had be worked out to limit this inefficiency – possible to limited extend only. So could it not be avoided that Concorde consumed some two tons of fuel taxiing to the runway. Because of the high fuel load that has to be carried every effort was made to save on weight - with the exception of the large sonic wine cellar. Aerodynamics are here essential and required the engines to be integrated with the delta wing with the land gear located underneath the engines which is not a particular safe place. Aerodynamics and structural integrity that had to be obtained with very thin skin and this required that riveted joints had to be eliminated. The lower skin has a thickness of only 1.2 mm. This meant that new manufacturing methods had

to be adapted if not developed, which resulted in a first time application of computer controlled manufacturing, a technology that was at that time still at its infancy but upon which the whole design concept would rest. New tooling had to be developed that sculps out major components out of aluminum and titanium blocks. This proved extremely difficult because of the toughness of the alloys and the often very thin components and close tolerances that had to be met. In the end this resulted in an aircraft with a take off weight of about 410,000 lbs (186,000 kg). Fuel included a staggering 50,4% - or more than double that of a 777 were fuel includes 24,1% of the take-off weight of about 520,000 lbs (235,900 kg). Concorde took up to 128 passengers against 383 with the 777.

Concorde flight 459

The circumstances surrounding flight 459 give an alarming insight in aviation safety - something one does not presume when you enter the plane and are welcomed with a glass of champagne. The flight lasted only sixty seconds and this was the result of design faults, total neglect during the 25 years of operation and a chain of dramatic events that started in the weeks preceding the particular flight.

Drama was set in motion during a maintenance stop in Tel Aviv, June 11th 2000, when a metal strip had to be replaced on one of the engines of a DC-10. About a month late, July 9th 2000, a mechanic at Continental noticed a twisted wear strip sticking out the same engine and this was replaced, but later it appeared that a wrong strip had be replaced and in a wrong way. Taking off just four minutes before the Concorde flight, the

strip was lost on the runway. Later it was found that runway inspection was conducted twice daily instead of the specified three. During a scheduled check 17 to 21 July the bogie had been replaced at the left main gear of the Concorde. By accident a spacer was left out, which means that the gear wheels track at a slight angle.

The chance to have a tyre incident increases with weight – with flight 459 structural weight was slightly exceeded. Standing on the platform ready to disembark it was found that there were 29 unidentified bags on board, which later proved to be 19. The bags had been X-rayed but the plane was already slight overweight and these bags were not in the crew's final determination of weight and balance of the aircraft. Also some extra fuel was carried for taxiing to provide more fuel for the actual flight. All this resulted in a slight overweight: maximum structural weight was 185.700 kg and the actual total weight 186.900 kg of which 94.800 kg fuel. The captain knew that he had to take off at structural limit.

A record of busted tires

Just passing *V1* on runway 26R the right front tire No 2 on the left main landing gear was destroyed after having run over the piece of metal - *tire burst happened fifty seven times before, nineteen times this was caused by foreign objects and twenty-two times during take off.* The destruction of the tyre in all probability resulted in large pieces of rubber being thrown against the underside of the left wing causing serious damage to the plane - *this happened twelve times before*. The impact led to the rupture of a part of tank No 5 - *penetration of a fuel tank happened six times before*

once right through the wing. This time a severe fire broke out under the left wing - *at an earlier accident probably a light fire occurred*. For the first time in twenty seven years a Concorde crashed and one hundred and thirteen persons lost their life and a lengthy investigation followed - *an investigation was performed happened one time before*. Concorde had a record of busted tires - *'The risk of a burst or deflated tire is 60 times greater on the Concorde supersonic jet than on the subsonic Airbus A340'* - well known to management, engineers and pilots. Not much was done about it. British Airways stopped using retreat tires back in 1981. Wheels and tires were strengthened in 1982, but not enough. Air France stopped using retreat tires not before 1996.

Cause of the accident

The accident happened after a piece of rubber from the busted tire slammed the wing underneath the fuel tank. From the accident records it is clear that the tires were not suited for a structural limit of 190.000 kg – a structural limit of 150.000 kg is probably a more realistic figure for the tires that were in place. The principal cause of the accident can therefore be regarded to be structural overweight with the tires that were in place. Tires should have been in place that can sustain the structural limit of 190.000 kg that was applied. Other factors contributed.

Investigation

From the investigation it is not clear how the accident exactly happened. The impactor that caused the accident was possibly a piece of

rubber that weighed some 4.5 kg. It is very difficult to estimate the impact velocity. The linear velocity of the aircraft (~85 m/s) is essentially relative but drag can cause extra acceleration. Probably more important are the peripheral velocity of the tire and the speed of possible self-rotation of the impactor where, depending on the direction of self-rotation this can add or lessen the actual impact velocity – in this case it probably added. Also the angle of impact has a strong influence on the impact force that is generated. Furthermore it is realistic to assume that more than one impactor was involved causing multiple impact that is known to increase breakage probability to a significant degree. Whatever, it will never be know, but the impact was apparently strong enough to cause significant damage - the long flame required a large quantity of kerosene - but it is not clear how this damage developed. Did the impact rupture the tank, puncturing a hole, or did it generate a hydrodynamic pressure surge in the fuel that blew up the tank. The latter mechanism does better explain how so much fuel could escape so fast – it is difficult to envisage this with a puncture. This is supported by the fact that earlier severe puncturing did not lead to catastrophe and also physical evidence supports the view that the integrity of the tank was broken.

Appropriate Measures

With so many unknowns it is very difficult to take appropriate measures to avoid such accident from happening again. Lowering the structural limit would mean definitively grounding the fleet, but it proved relatively easy for Michelin to develop a burst resistant tire – which

essentially solved the problem. The investigators deemed it necessary also to strengthen the tank for impact resistance and to protect certain cabling with armour plating. The tanks were only extra protected for penetrating impact with a Kevlar lining, although hydrodynamic ram is a most probable cause. Making the tanks strong enough to withstand a pressure wave would require the tank to be provided with wave absorbing panels and this would limit the fuel capacity to a level were transatlantic crossing could require a fuel stop at Shannon – and was not considered. Rubber projectiles were fired at a Kevlar-strengthened tank, which created holes, but these were *'only big enough to release a mere one litre of kerosene per second'*. For the engineers involved apparently enough proof that impact should no longer cause a fire risk although it is still unclear what caused the fire. It is very difficult to ignite kerosene, but ignition took place almost immediately. The investigators perceived engine surge, electric arc and hot contact. Also here it is probably a coincident combination of these and possibly other mechanism. The investigation report reads *'Although the engineers could not be 100% certain, they felt that their best educated estimate was that the ignition was caused by a spark from arcing in the landing gear brake cabling. It was proposed that this would be armoured in the remaining aircraft'*. What also contributed to the accident are the very thin skin of the fuel tanks and the close positioning relative to each other and to the fuel tanks, the engines and the landing gear - but making such fundamental improvements would mean building a new aircraft - and this also was not considered.

Concorde's Return to Service Program took some fifteen months of

hard work, but as has been shown, the most important modifications were relatively simple. Concorde was declared air-worthy again and re-certified. Amazingly in the official investigation report cites only previous tire problems - no attention was paid to the many other accidents that happened during earlier service. A quick look through the Concorde's past accident history learns - amongst others - that part of the rudders broke off four times, sometimes large sections and at least one engine had to be shut down nine times. With regard to the accident here discussed the fundamental question remains why improved tires were not developed and installed at a much earlier stage. Managers, engineers, mechanics and also the pilots are here to blame.