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Key lessons from the Boeing 737 MAX 8 accidents

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Summary

In 2018 and 2019, two Boeing 737 MAX 8 aircrafts crashed, resulting in a combined total of 346 fatalities. Investigations revealed that both planes fell to the ground under similar circumstances; an incorrect sensor reading erroneously activated the aircrafts' new flight control system called MCAS, forcing the planes into an uncontrollable nosedive. Further analysis concluded that the design and certification process of the 737 MAX 8 was rushed; pilots and aircraft maintenance engineers were inadequately trained in the operation of the new aircraft, and several incident reports leading up to the crashes were not thoroughly investigated. This article discusses the nature of these accidents and extracts key lessons which can be applied in chemical engineering and other high-risk industries.

Keywords: Lessons from other industries

Background

The root causes of the accidents can be traced back to a chain of poor decisions Boeing made in a fervent effort to keep up with technological advances and market pressures. In 2010, Boeing's main competitor, Airbus, launched the A320neo; an aircraft boasting a 10-15% higher fuel efficiency than the Boeing's flagship model – the 737NG. The A320neo soon became the fastest-selling plane in the world. In order to maintain a competitive position, Boeing needed to launch a comparable aircraft with an increased fuel efficiency, and in 2011, the company announced the development of the 737 MAX 8[1,2].

This aircraft was fitted with a new instrumented system called the Manoeuvring Characteristics Augmentation System, or MCAS, whose purpose was to stabilise the aircraft in the event it pitched up at an exceedingly high angle of attack (AoA). Maintaining the correct AoA is crucial in aviation as failure to do so may lead to an aerodynamic stall[1,3]. The MAX 8's tendency to pitch up was a direct result of the repositioning of the engines on the new model, highlighting a major flaw in the design ethos of the aircraft. Boeing's first mistake was the poor positioning of the engines. Their second mistake was their resolve to rely on an instrumentation system to fix an inherently unstable design. Engineering designs should be innately safe. Safety related control systems like MCAS serve as a final barrier to prevent a disaster and should not form a part of normal operation. To make matters worse, Boeing did not disclose the existence of MCAS to pilots, leaving them to operate an aircraft they did not fully comprehend.

Although the MAX 8 was equipped with two AoA sensors – one on either side of the aircraft's nose[1] – MCAS was designed such that a high AoA reading from only one of these sensors would activate the system and force the aircraft's nose down. In addition to the failure of MCAS, common to both accidents, a deeper analysis unearths many operational and managerial failings that equally contributed to the crashes.

The accidents

Flight JT43 incident and Flight JT610 crash

On 29 October 2018, Lion Air flight JT610 crashed into the Java Sea, killing everyone on board[4]. Prior to the accident, this same aircraft (PK-LQP) had been involved in several minor incidents[5] relating to the false activation of MCAS. One example was its penultimate flight on 28 October 2018, during which MCAS was fed incorrect data from one of the plane's AoA sensor and as a result of this the aircraft's nose was forced downwards[4]. However, having realised the problem in time, an off-duty pilot in the cockpit was able to guide the crew to disable MCAS and save the plane[5]. Flight-tracking data confirmed the incident with recordings of irregular velocities, altitudes and directions. Nonetheless, the plane was cleared to fly again the following day. The aircraft took off for the last time from Jakarta International Airport at 0620 local time, and by 0633, it had crashed.

The recovered flight data recorder and cockpit voice recorder from flight JT610 revealed that the source of the accident was, again, inaccurate velocities, AoA and altitude data, which had wrongly triggered MCAS to nosedive. Sadly, this time the pilots were unable to regain control[6]. As the aircraft had only reached an altitude of 5,000 metres before MCAS activated, there was insufficient time to disable the system and prevent the crash[6,7].

Flight ET302 crash

On 10 March 2019, five months after PK-LQP crashed, another MAX 8 jet, ET-AVJ, crashed in the Ethiopian countryside[8]. A mere ten seconds after take-off, an AoA sensor alarm activated, once again reporting a false reading indicating that the aircraft was in a near-vertical orientation[9,10]. This triggered activation of MCAS, which the Captain and First Officer

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repeatedly attempted to disengage[10]. Tower controllers soon lost contact with the pilots just six minutes after departure — the plane had crashed killing all who were aboard[10,11].

Consequences

Following the crash of Flight ET302, aviation authorities across the globe grounded 737 MAX 8 aircrafts. However, the United States Federal Aviation Administration (FAA) waited and allowed the fleet to operate until 13 March 2019[12, 13]. Both the FAA and Boeing's CEO initially placed blame on the Lion Air and Ethiopian Airlines crews, stating that MCAS was only a part of a "chain of events" that led to the accidents[14]. Such comments made headlines and sparked conversations within the aviation community regarding safety responsibility[14]. In the months that followed, Boeing faced unprecedented amounts of scrutiny with CNN describing the backlash as an "international firestorm"[13]. Boeing lost over $40 billion in value and the United States Department of Justice launched a criminal investigation into the company[13, 15]. During the inquiry, concerns were raised regarding the technical and engineering failures that contributed to the crash, as well as Boeing's rush to bring this new aircraft model to the market[12, 13, 15].

Design flaws

The design objective for the 737 MAX 8 was to provide a higher fuel efficiency than the 737NG. To achieve this, Boeing opted to use an engine that was diametrically 6-inches larger than that of the 737NG to allow for an increase in propulsion efficiency and thus a reduced energy demand[2]. There were two major consequences to using larger engines. First, the aircraft would experience a higher drag force, and second, the engines would not satisfy the ground clearance regulations if placed in the same position as those on the 737NG. Thus, the engine nacelles were positioned further forward and raised higher under the wing than those in the 737NG. These alterations resulted in the formation of an aerodynamic moment which would cause the nose of the aircraft to tilt up and increase the plane's AoA. Past a critical value, an increase in the angle of attack no longer increases the resultant lift significantly, but could instead induce aerodynamic stall, and thus, a potential crash.

To prevent aerodynamic stalls, Boeing developed and installed MCAS[3]. The control loop flow was as follows. If the angle of attack was sensed too high, the signal from the AoA sensor would activate MCAS. MCAS would then reduce the angle of attack by engaging the nose-down position until the aircraft was stabilised horizontally via an automated trim stabiliser[1]. It is important to note that AoA sensors have a history of technical failures starting from the 1990s[16], bringing their reliability into question. This makes Boeing's decision to design MCAS such that it could be triggered by a single AoA sensor rather poor, especially considering that the safety instrumentation systems in previous 737 models had relied on both sensors[1].

Was the Boeing 737 MAX 8 design and certification process to blame?

The FAA certified the Boeing 737 MAX 8 in March 2017. The certification process took approximately five years to complete – the usual period for this type of certification. On first glance, it appeared the FAA followed standard practices and fulfilled their duty in ensuring the new aircraft was fit to fly. Despite this, the ensuing crashes prompted the US congress to order an investigation. Their concluding report, issued on 16 September 2020, put the blame on Boeing and the FAA for lapses in the aircraft's design and certification process[17].

The main failings of Boeing and the FAA, and the loss prevention lessons we can derive from them, are as follows:

Flawed safety culture

In March of 2016, during the development of the MAX 8, Boeing approved changes to the MCAS which would increase its authority to push the airplane's nose down under certain conditions. Following the redesign, Boeing immediately removed all references to MCAS from their Flight Crew Operations Manual (FCOM). This decision to remove MCAS from the pilot handbook was authorised by the FAA and no questions or concerns were raised. Following the Lion Air crash, it became known that the FAA officials who authorised this request were unaware of the redesign of MCAS[16]. This incident highlights Boeing's tendency to conceal critical information from the FAA, as well as the FAA's complacency in managing Boeing's actions. The omittance of additional pilot training to address the change in aircraft operation highlights Boeing's propensity to cut costs and prioritise profitability over safety. Ironically, investing more money in pilot training would have cost Boeing significantly less than the £1.86bn[18] settlement paid in fines and compensation following the crashes. Arguably, Boeing's poor communication and concealment of critical information for personal gain stem from a deeper issue; that of a flawed safety culture. Boeing's response to the crashes should go beyond individual failures and technical flaws. Instead, they should work to establish a strong safety culture and instil a commitment to health and safety in all company employees starting from the top to avoid similar incidents in the future.

Lesson: Companies should disclose all safety related information to the appropriate regulatory bodies and face consequences if they fail to do so. More than that, safety should be ingrained in the company culture and placed above other business priorities. With safety at the heart of the company, employees will make better and more ethical decisions that ultimately lead to fewer incidents.

Weak oversight structure on part of the FAA

The report issued by the U.S. Congress presents incidents where safety concerns raised by the FAA's own technical experts were overruled at the request of Boeing[16]. The report also documents instances in which Boeing employees were authorised to perform work on behalf of the FAA and failed to alert the FAA to potential safety issues they encountered[17].

Lesson: Regulatory bodies, such as the FAA, should act with the sole aim of protecting the public from unnecessary risk, thus more independent checkpoints may be introduced to minimise accidents which root back to company safety culture. If the FAA listened to their own employees and strengthened their oversight of Boeing, the flawed aircrafts as they were may have never entered the market[19]. Duties such

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as carrying out inspections and vetting new aircraft designs should be completed by FAA officials, not passed down to industry employees. Regulators should maintain sufficient independence from the corporations they regulate.

Insufficient pilot training to manage the redesign of MCAS

MCAS was omitted from all aircraft manuals and flight crews had no knowledge of its existence prior to the Lion Air crash. Boeing failed to provide training in the function and operation of MCAS, therefore pilots were in no way equipped to mitigate any potential malfunction of the software during flight[17].

Lesson: Employees need to be educated in all aspects of the design, normal operations, and potential accidents, particularly those pertaining to safety.

FAA slow to act despite known risk

In December 2018, the FAA privately predicted that MCAS could cause 15 crashes over 30 years[20]. Despite this knowledge, the FAA resisted grounding the Boeing 737 MAX 8 aircraft until the second accident occurred, and it was one of the last regulators to do so. If the FAA grounded the plane when they first became aware of MCAS' potential dangers, the second crash, and thus the deaths of 157 people, would have been avoided. The negative economic impact of grounding an entire line of commercial aircraft would have been enormous, and it is not impossible that this recommendation would have been met with high criticism of the FAA from aircraft operators. The prediction could have been followed up by deeper investigations into the incidents leading up to the first crash and results taken to Boeing to further improve the design of the aircraft's MCAS.

Lesson: Following a fatal safety accident, operation should be halted until the cause is fully understood so that similar accidents can be avoided in the future regardless of the resulting economic cost. The safety of passengers and preservation of life should be prioritised.

Conclusion

This article has looked at the causes of the Boeing 737 MAX 8 accidents and the shortcomings of loss prevention efforts by the organisations involved. Arguably, the root of the accidents is the flawed safety culture which was practiced at Boeing. From the rushed design process and lax safety checks to Boeing's failure to act on incident reports, many corners were cut in favour of cutting costs and bringing the aircraft to market as quickly as possible. Lessons taken from these accidents can be applied to the chemical engineering industry and serve to remind us that safety starts from the top. Management decisions should not be made without consulting company employees, particularly those having expertise in the area, and safety should be placed above all other situational factors affecting the decision.

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