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Network Analysis of Crew and Air Traffic Controller Actions in Case of Engine Problems on Multi-engine Aircraft during Take-off

The emergency situation that arises on board an aircraft when one engine fails and other engine fires on the same side during the take-off was formalized. A network analysis of the emergency situation in flight was carried out and a deterministic model of the crew and air traffic controller actions during parrying an accident in flight was obtained.

Problem statement. The profession of air traffic controller (ATC) is one of the most stressful. The ATC is responsible for the life and health of people both in the air and on the ground, as well as for the expensive technique. He is compelled to constantly keep in mind a huge amount of information, analyze, predict the air situation, make non-standard decisions, which requires independent original thinking [1]. During emergency situations (ES) in flight, the main role in ensuring the safety of flights is usually given to the crew, as the decision on the order of the flight in the ES is taken by the First pilot (FP) and he is responsible for the decision. In this case, it is necessary to consider that the FP decision is based on the information and recommendations of the ATC. In turn, the ATC is responsible for the accuracy and timeliness of the information and advice given to the crew, so the ATC in such situations is given a significant role [2]. The main requirement for the ATC during ES is the constant readiness to provide the necessary assistance to the crew depending on the type of situation, taking into account the air situation and meteorological conditions.

The purpose of the publication. To solve the problem of optimizing the pilot and the ATC interaction during ES by developing decision-making and flight situation development models, that will increase the efficiency and quality of decision-making in unusual/emergency flight situations [3, 4].

Main part. To investigate the interaction between the aircraft crew and the ATC during ES, consider the incident on November 28, 2010, with the aircraft IL-76TD of the Sun Ways Airlines, which performed a flight from Karachi to Khartum with a cargo weighing 31 tons [5]. Immediately after take-off, one engine failed, and then a nearby engine fired. The flame of the engine was noticed from the ground, about which the ATC from the Tower informed the FP. The crew tried to make an emergency landing.

At 1:48 local time (UTC + 5), in four minutes after takeoff, the plane fell to the open ground (six km from the end of the runway). All the crew of the aircraft (eight people) and four people on earth perished. During the accident investigation, it was discovered that at the time of the fall of the plane, two of the four engines of the aircraft did not work.

On the basis of the flight simulator KTS-32 (aircraft IL-76TD), a simulation of the crew and the ATC actions in the case of one engine fails and other engine fires on the same side during the take-off. Three possible scenarios of the ES development were investigated:

- the FP makes a decision to land making "turn 2*180 degree";
- the FP makes a decision to land "with a return heading";
- the FP makes a decision to land directly in front of him.

Different meteorological conditions were created; the cargo weight, the centering of the aircraft, the airport charges, etc. were changed.

Based on the obtained results, a deterministic model of the crew and the ATC actions during ES – one engine fails and other engine fires on the same side during the take-off – was developed. In Table 1 is shown the structural-time table of the crew and the ATC actions during ES when one engine fails and other engine fires on the same side during the take-off.

Table 1

Structural-time table of the crew and the ATC actions during ES when one engine fails and other engine fires on the same side during the take-off

<table>
<tr><th>Phase</th><th>Action</th><th>Description of crew action</th><th>Relies on action</th><th>Action time, t, sec.</th><th>Action</th><th>Description of ATC action</th><th>Relies on action</th><th>Action time, t, sec.</th></tr>
<tr><td rowspan="6">I</td><td>a_1</td><td>Flight engineer (FE) detects engine failure</td><td>-</td><td>2</td><td rowspan="3">-</td><td rowspan="3"></td><td rowspan="3">-</td><td rowspan="3">-</td></tr>
<tr><td>a_2</td><td>FE reports FP about engine failure</td><td>a_1</td><td>2</td></tr>
<tr><td>a_3</td><td>FP gives FE order to shut down a failed engine, gives radio operator (RO) order to switch off a generator</td><td>a_2</td><td>4</td></tr>
<tr><td>a_4</td><td>FP gives RO order to report ATC about failure</td><td>a_3</td><td>2</td><td rowspan="3">b_1</td><td rowspan="3">Receives engine failure report from the crew</td><td rowspan="3">-</td><td rowspan="3">5</td></tr>
<tr><td>a_5</td><td>FP gives FE order to retract gears</td><td>a_4</td><td>2</td></tr>
<tr><td>a_6</td><td>FP reduces the rate of climbing, continues to take off</td><td>a_5</td><td>4</td></tr>
<tr><td rowspan="3">II</td><td>a_7</td><td>Voice informers "Fire", the lighting of the red signal board</td><td>a_6</td><td>2</td><td rowspan="3">b_2</td><td rowspan="3">Receives engine fire report from the crew</td><td rowspan="3">b_1</td><td rowspan="3">8</td></tr>
<tr><td>a_8</td><td>FE detects the number of the engine in fire</td><td>a_7</td><td>3</td></tr>
<tr><td>a_9</td><td>FP gives RO order to report ATC about the engine fire</td><td>a_8</td><td>3</td></tr>
</table>

	a_{10}	FP sets horizontal flight for increasing speed of flaps, slats retraction	a_9	30				
	a_{11}	FP gives FE order to retract slats	a_{10}	4	b_3	Reports FP about external features of failure, fixes the time	b_2	10
	a_{12}	FP gives FE order to retract flaps	a_{11}	5	b_4	Checks setting by FP the emergency code on the aircraft transponder	b_3	5
	a_{13}	FE reports FP about slats and flaps retraction	a_{12}	15	b_5	Reports supervisor about emergency case	b_4	5
	a_{14}	FP sets transponder emergency code	a_{13}	4	b_6	Clears airspace in close proximity to aircraft	b_5	15
	a_{15}	FP gives FE order to shut off the engine, close fuel valve, switch on fire extinguishing system	a_{14}	8	b_7	If necessary sets of radio silence	b_6	4
	a_{16}	FE check fire in the engine, switch on the second bottle of fire extinguish system, then the third bottle	a_{15}	30	b_8	Clarifies further FP intentions for immediate landing at the departure aerodrome	b_7	10
	a_{17}	FE reports FP about the fire is extinguished or not	a_{16}	2	b_9	Promotes the implementation of the decision	b_8	37
					b_{10}	Submits information about the emergency board	b_9	5
					b_{11}	Asks meteorological station about weather conditions for landing	b_{10}	5
III	a_{18}	FP reports ATC about the fire is extinguished or not, and landing decision	a_{17}	10	b_{12}	Clarifies whether they managed to extinguish the engine fire	b_{11}	10
					b_{13}	Ensures an emergency landing of the aircraft	b_{12}	4
	a_{19}	FP makes an approach, gives FE order to extend gears, slats, flaps	a_{18}	77	b_{14}	Gives instructions for approach, informs about the direction and speed of the wind	b_{13}	8
					b_{15}	Controls the movement of the	b_{14}	64

						aircraft, inform FP about deviation from the heading and glide path		
	a_{20}	FP gives FE order to switch on a hydraulic pump of the failed hydraulic system	a_{19}	3	b_{16}	Transfers controlling to the Tower	b_{15}	4
IV	a_{21}	FP performs a landing	a_{20}	30	b_{17}	Clears runway according to local instructions	b_{16}	10
	a_{22}	After stopping on the runway, if the fire is not extinguished, turns aircraft face to the wind	a_{21}	10	b_{18}	According to the supervisor order, sets readiness of rescue means	b_{17}	5

The time required to perform actions aimed to ES parrying was measured during simulator training of Ukrainian flight crews and ATC, pilots and air force commanders of Ukraine Air Force, as well as crews of several foreign airlines.

With the help of network planning, the crew and the ATC actions was synchronized, resulting in the determined time of execution of actions by operators at the stages of ES parrying, namely: phase 1 – the engine failure; phase 2 – the other engine fire on the same side; phase 3 – the approach; phase 4 – the emergency landing. The obtained data were statistically processed, their statistical characteristics are within the permissible limits: the standard deviation does not exceed 0,5 sec.; the coefficient of variation does not exceed 19%. Therefore, the average results can be considered reliable. An assessment of the competence of specialists who participated in the research was also carried out, by analyzing their professional activity, the latitude of outlook and general erudition.

The network graph (Fig. 1) of the crew and the ATC actions during ES (one engine failure and other engine fire on the same side during the take-off) allows to determine the critical time depending on the decision-making by the FP (to land at the departure aerodrome with direct or reverse heading), which is $T_{crit\ direct}$ = 6 min. 02 sec. and $T_{crit\ reverse}$ = 4 min. 10 sec. respectively. Consequently, depending on the conditions and circumstances, in case of such failures, the aircraft will perform landing sooner with the reverse heading. So, this is the best alternative for completing the flight.

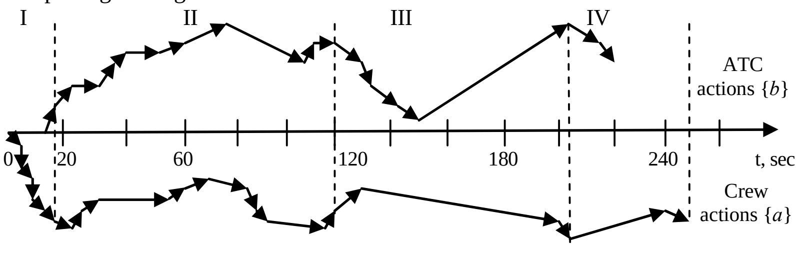

Fig. 1. A network graph for the crew and the ATC actions during ES when one engine failure and other engine fire on the same side during the take-off

In this context, the use of flight simulators in the process of ATC professional training is relevant. They will help ATC to get acquainted with the situation in the crew cabin and the indicators of the aircraft equipment during the ES. At the same time the ATC:

• will get the experience of the crew member during the ES;
• will pay attention to how the ATC intervention can disrupt crew members;
• will perform exercises on radio communication during the ES;
• will execute the ES checklist;
• will participate in the FP decision-making during the ES;
• will observe the features of aircraft going around.

During ES the ATC is advised to use the checklist that will help to handle incidents in order to establish optimal actions to achieve better cooperation between the pilot and the ATC. An observer, working with the ATC, using a checklist can provide better support as he will more clearly understand the technology of the ATC in a specific ES.

Conclusion

The design and calculation of scenarios of the flight situations development and the forecasting of possible human-operator actions in ES will provide an opportunity to prevent the negative development of the emergency situation in a catastrophic one.

The proposed models will allow supplying the database of flight scenarios development in the Decision Support System of the pilot / ATC and can be used later in the training process of the Air Navigation System operators, as well as in the actual operating conditions of the aircraft.

References

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