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RELIABILITY ANALYSIS OF AIRCRAFT FLEET IN NIGERIA

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Abstract

This article is devoted to the reliability analysis of aircraft in Nigeria as well as their systems and structures during operation. This is necessary for the development of methods for diagnosing technical conditions and the optimization of aircraft maintenance programs. The results of this study identify factors affecting flight safety in terms of reliability parameters which are presented in this article.

Keywords: aircraft; reliability; technical condition; diagnosis; maintenance

1. Introduction

This article discusses the reliability of helicopters and aeroplanes as well as their systems and structures, for the development of optimal maintenance programs to ensure the highest level of flight safety.

During the reliability analysis, the following parameters were determined: mean time between failures ($T_{\sum}$), coefficient ($K_{1000\sum}$), and failure rate ($\lambda_{\sum}$). These results will be used as source data for the development of a mathematical model for the optimization of maintenance processes of aircrafts in Nigeria

2. Reliability analysis

The analysis was carried out using data provided by airlines, helicopter operators and the Nigerian Civil Aviation Authority (NCAA). Data for helicopters: seven S–76c++ and four S–92, and aeroplanes: three MD–83, two ERJ–135 and two ATR 42–300 for the period 2014 – 2018 were used. A basic sample of statistical data was generated for all 18 aircraft and the total flight time was 67360.96 flight hours. The MD–83 and ATR 42–300 aircraft were produced before 1999 and are considered an “aging” aircraft fleet.

During the operation of these aircraft, 49 incidents occurred of which 13 were classified as serious incidents [1]. The distribution of these incidents by operational factors is shown in Fig. 1.

The main factor that led to these incidents was technical factor (alongside design and production errors), which accounts for 43% of the total number of factors. Environmental factors including ornithology accounts for 39% and human factors (crew, maintenance and air traffic control personnel) – 18%.

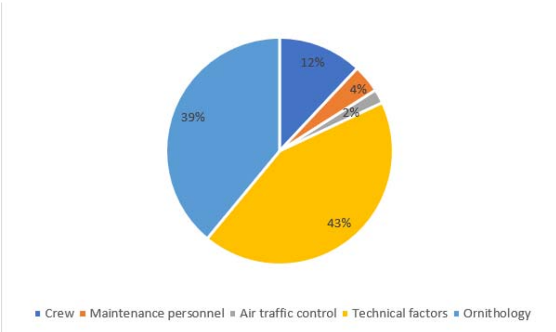

Fig. 1. Distribution of incidents according to operational factors

The data used for the reliability analysis of the S76c ++ helicopters is presented in Table 1, and the distribution of the number of failures, according to systems and structures is shown in Table 2.

Table 1

Failure information for S76c++ helicopters

Registration №	**Flight Hours**	**Failures**	
		Total	**In–Flight**
5N-KAC	4187.02	177	36
5N-CHI	4417.52	271	20
5N-ANG	4640.67	245	25
5N-NKE	3943.20	120	18
5N-EJI	4628.91	116	32
5N-OBI	3122.83	433	143
5N-PRE	4175.96	314	74
Total	**29116.11**	**1676**	**348**

Table 2

Failure information of systems and structures in the S76c ++ helicopters

ATA №	ATA Chapter Name	Total	In-Flight
21	Air conditioning	11	3
22	Auto flight	104	49
23	Communications	39	12
24	Electrical power	57	20
25	Equipment/furnishings	27	2
26	Fire protection	15	
28	Fuel	9	3
29	Hydraulic power	46	3
30	Ice and rain protection	14	4
31	Indicating/recording systems	31	18
32	Landing gear	211	16
33	Lights	76	16
34	Navigation	173	91
39	Electrical - electronic panels and multipurpose component	9	2
45	Onboard maintenance systems	17	1
51	Standard practices and structures	70	3
52	Doors	53	7
53	Fuselage	165	21
55	Stabilizers	13	
56	Windows	4	
65	Tail rotor drives	192	8
66	Folding blades	37	4
67	Rotor flight control	76	12
71	Power plant	24	2
72	Engines	20	6
73	Engine fuel and control	48	16
74	Engine ignition	1	
75	Engine air	54	18
76	Engine controls	5	1
77	Engine indicating	8	6
78	Engine exhaust	4	
79	Engine oil	48	1
80	Starting	15	3
Total		**7143**	**4921**

The reliability parameters [2] were calculated as follows:

1. $T_{\Sigma} = t / n$, where t is the total flight hours and n is the number of failures for the given period.
2. Number of failures per 1000 flight hours. $K_{1000} = (n / t) * 1000$.
3. Failure rate $\lambda_{\Sigma} = 1 / T_{\Sigma}$

The total mean time between failures (T_{Σ}) and in-flight mean time between failures (T_F) of the top 10 failing systems and structures of the S76c ++ helicopters are shown in Fig. 2. and Fig. 3.

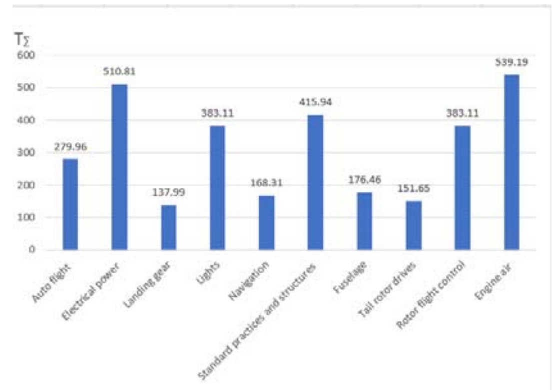

Fig. 2. T_{Σ} of the top 10 most failing systems and structures in the S76c++ helicopters

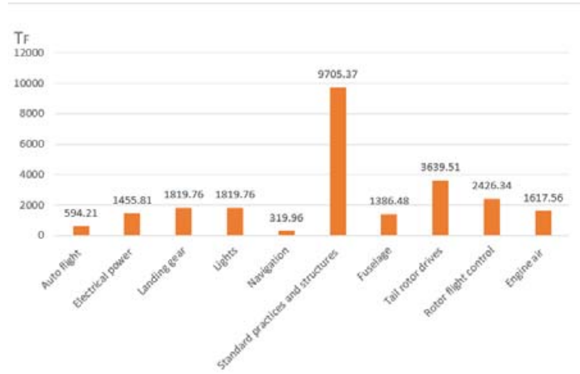

Fig. 3. T_F of the top 10 most failing systems and structures in the S76c++ helicopters

As shown in Fig. 2 and Fig. 3 most failures occur on ground and to a lesser extent in-flight. The dynamics of the failure rate (λ_{Σ}) in the S76c++ and S92 helicopters for the period 2014–2018 is shown in Fig. 4.

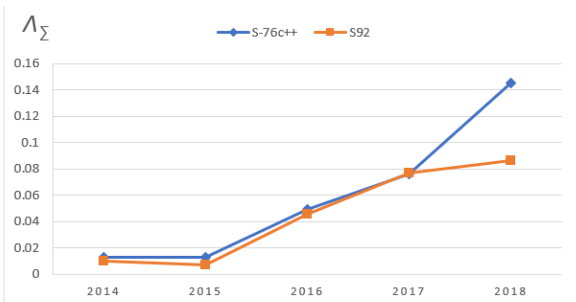

Fig. 4. Dynamics in λ_{Σ} for S76c ++ and S92 helicopters

It can be seen from the figure that the transition period from the normal operation phase (2014 – 2015) to the third operational phase is clearly traced – the stage of increased wear of helicopter parts, where the failure rate increases (2016 - 2018) [4]. A similar analysis was carried out for the S92 helicopters and the dynamics observed were comparable to that of the S76c ++ helicopters. The systems and structures with the lowest level of reliability are air conditioning, automatic flight control, landing gear, navigation, fuselage, doors, main rotor, main rotor drives, tail rotor and tail rotor drives. Reliability parameters of the S76c ++ helicopters for the period under consideration are $T_\Sigma = 17.37$, $K_{1000\Sigma} = 57.56$ *and* $\lambda_\Sigma = 0.058$. For the S92 helicopters $T_\Sigma = 18.25$ $K_{1000\Sigma} = 54.81$ *and* $\lambda_\Sigma = 0.055$.

For the reliability analysis of aeroplanes, ERJ–135 (manufactured in 1999), ATR 42–300 (manufactured in 1993) and MD 83 (manufactured 1990 –1991) were analyzed. As an example, the data used for the analysis of the MD–83 aeroplanes are given in Tables 3 and 4.

Table 3

Failure information for MD–83 aeroplanes

Registration №	Flight Hours	Failures	
		Total	In-flight
5N-UTO	5994.42	2795	1949
5N-JOE	5829.25	2626	1853
5N-ZOE	4182.66	1722	1119
Total	**16006**	**7143**	**4921**

The total mean time between failures (T_Σ) and in-flight mean time between failures (T_F) of the top 10 failing systems of the MD–83 aeroplanes are shown in Fig. 5. and Fig. 6.

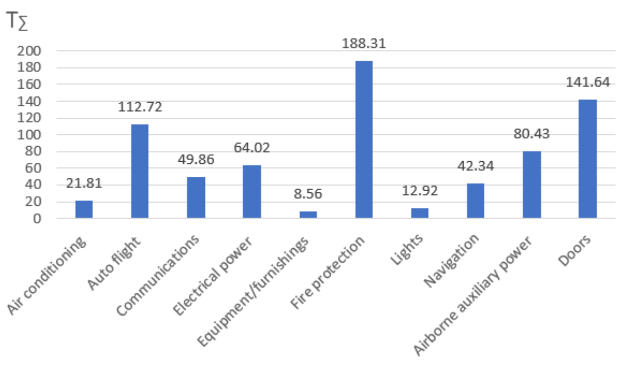

Fig. 5. T_Σ of the top 10 most failing systems in the MD–83 aeroplanes

Table 4

Failure information of systems and structures in the MD–83 aeroplanes

ATA №	ATA Chapter Name	Total	In-Flight
21	Air conditioning	734	670
22	Auto flight	142	119
23	Communications	321	272
24	Electrical power	250	152
25	Equipment/furnishings	1869	1752
26	Fire protection	85	38
27	Flight controls	104	87
28	Fuel	62	30
29	Hydraulic power	52	32
30	Ice and rain protection	77	67
31	Indicating/recording systems	30	25
32	Landing gear	965	209
33	Lights	1239	613
34	Navigation	378	285
35	Oxygen	73	28
36	Pneumatics	30	27
38	Vacuum	68	60
39	Airborne auxiliary power	1	1
45	Onboard maintenance systems	1	1
46	Information systems	2	2
49	Airborne auxiliary power	199	107
51	Standard practices and structures	6	2
52	Doors	113	104
53	Fuselage	8	1
56	Windows	26	22
57	Wings	3	2
71	Power plant	28	22
72	Engines	46	38
73	Engine fuel and control	52	34
74	Engine ignition	12	5
75	Engine air	22	10
76	Engine controls	18	13
77	Engine indicating	29	24
78	Engine exhaust	21	13
79	Engine oil	37	25
80	Starting	40	29
	Total	**7143**	**4921**

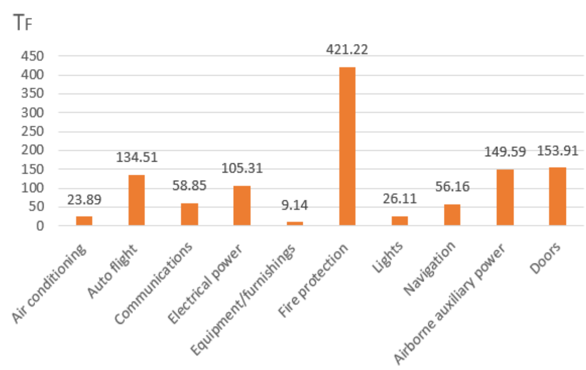

Fig. 6. T_F of the top 10 most failing systems in the MD–83 aeroplanes

Reliability parameters for the MD–83 aeroplanes are $T_{\sum} = 2.24$, $K_{1000\sum} = 446.26$ and $\lambda_{\sum} = 0.446$.

For the ERJ–135 aeroplanes the topmost failures were found in air conditioning system, communication equipment, electric power, furnishings, flight controls, indicating/recording systems, landing gear, lights, navigation equipment and pneumatic system. Reliability parameters for the ERJ–135 aeroplanes for the period under review are $T_{\sum} = 6.27$, $K_{1000\sum} = 159.37$ and $\lambda_{\sum} = 0.159$.

For the ATR 42–300 the topmost failing systems were: air conditioning system, communication equipment, electrical power, furnishings, fuel system, ice and rain protection, landing gear, lights, navigation equipment and engines. Reliability parameters are $T_{\sum}=13.24$, $K_{1000\sum}=75.51$ and $\lambda_{\sum}=0.076$.

Fig. 7 shows the dynamic change in failure rate for all the aeroplanes which were studied.

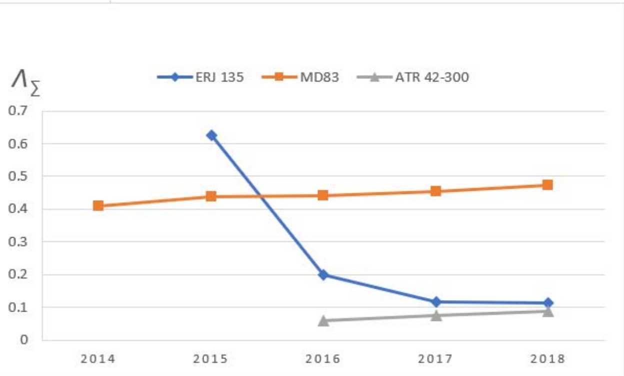

Fig. 7. Dynamics in $\lambda_{\sum}$ for ERJ–135, MD–83 and ATR 42–300 aeroplanes

Apart from the ERJ–135 fleet, the other aeroplanes are in the third stage of the reliability curve characterized by increased wear hence they are considered an “aging” fleet [4]. For ERJ–135 aircraft manufactured in 1999, the initial decrease (2015 – 2017) in failure rate can be linked to major repairs carried out before its first flight in 2015 by the current operator.

4. Conclusions

Except for the ERJ–135, the aircrafts studied are considered an “aging” fleet with relatively low reliability indicators, which are at the third stage of operation — the stage of increased wear of aircraft systems and structures. Based on this, it is necessary for the airlines and helicopter operators to adjust their maintenance programs and spare parts supply plans.

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О.Ч. Окоро

Аналіз надійності приписного парку повітряних суден авіакомпанії Нігерії

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Стаття присвячена аналізу показників надійності приписного парку літаків і вертольотів авіакомпанії Нігерії, а також їх функціональних систем в процесі експлуатації. Це необхідно для розробки засобів і методів діагностування технічного стану і формування оптимальних програм технічного обслуговування повітряних суден. Представлено результати досліджень з виявлення факторів, що впливають на безпеку польотів і найбільш критичні функціональні системи повітряних суден, з точки зору показників надійності.

Ключові слова: повітряне судно, надійність, технічний стан, діагностування, технічне обслуговування

О.Ч. Окоро. Анализ надежности приписного парка воздушных судов авиакомпании Нигерии

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Статья посвящена анализу показателей надежности приписного парка самолетов и вертолетов авиакомпании Нигерии, а также их функциональных систем в процессе эксплуатации. Это необходимо для разработки способов и методов диагностирования технического состояния и формирования оптимальных программ технического обслуживания воздушных судов. Представлены результаты исследований по выявлению факторов, влияющих на безопасность полетов и наиболее критичные функциональные системы воздушных судов, с точки зрения показателей надежности.

Ключевые слова: воздушное судно, надежность, техническое состояние, диагностирование, техническое обслуживание.

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