Engineering Failure Analysis xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Analysis of Boeing 737 aircraft towing accidents

Shu-wen Chen*, Hui Liu, Fu-hai Li

Nanjing University of Aeronautics and Astronautics, China

ARTICLE INFO

Keywords:
Down drag
Shear pins
Joint gaps
Failure analysis

ABSTRACT

The aim of the current study is to analyze the failure reasons of towing accidents happened in 2004 and 2005. We found joint gaps were between aircraft-towbar-tractor which might been the possible cause of failure. Fracture analysis techniques were performed to the fracture of down drag, shear pins and etc. The dynamic simulation was performed to analyze the impact of joint gaps on the load of down drag. The result confirmed that down drag and shear pins were overload fracture caused by great impulse towing load caused by joint gaps between aircraft-towbar-tractor under uncommon situations, and the structure of towbar should to be improved as the utilizes of shear pins to guarantee the security of towing system was not enough.

1. Introduction

The safety of aircraft towing is an important part in aviation security. Failure cases happened during the progress of towing and parking were not rare [1] due to bad working circumstance, human error, etc. Towing operation regulations have been standardized to update limitations of towing speed and braking force [2]. Gustavsson and Radev et al. [3,4] analyzed the towing load under different working conditions and flight phases. Tsybanev et al. [5] evaluated bearing force of nose landing gear by FEM.

Two towing accidents of Boeing 737-300 aircraft were discussed in this paper. The first accident happened on July 2004 while the operator was braking the tractor suddenly. Another accident happened on June 2005 while the towing system was passing through the trench of oil filler pipes on tarmac.

We mainly analyzed the down drag of nose landing gear and the shear pins of towbar in these two cases and found the failure modes of these two accidents were alike. Furthermore, we found obvious joint gaps between aircraft, towbar, and tractor through field investigation which might have been the cause of impulse load during towing. The following section will describe the details of the carried out experimental and numerical researches to identify the fracture mode and the reasons of failure.

2. Failure analysis

2.1. Fraction description

The nose of aircraft pressed down on towbar in both failure cases, as shown in Fig. 1. Several structures of nose landing gear were damaged that the down drug and the lock link of nose landing gear were ruptured. A large area of depression and a crack were found on the nose gear well aft bulkhead, as shown in Fig. 2. The other areas of nose landing gear were found some mechanical scratches.

Some cracks were found in the towbar. Fig. 3 showed the rupture of the upper lug of towbar. Shear pins of towbar were fractured into three segments, as shown in Fig. 4.

* Corresponding author.
E-mail address: csw_nuaa@126.com (S.-w. Chen).

http://dx.doi.org/10.1016/j.engfailanal.2017.06.024
Received 9 September 2016; Received in revised form 3 June 2017; Accepted 14 June 2017
1350-6307/

Fig. 1. The failure state of aircraft.

2.2. Fracture analysis

The rupture of down drag was happened in the middle position, and the trailing edge of sectional I-beam was obviously shrinkage deformation near the fracture of down drag. Experimental examinations were performed to fractured structures (taken the observer face to the aircraft as the reference orientation), and the fracture morphology of down drag and shear pins of towbar were shown in Figs. 5 and 6, respectively. The chemical composition of down drag is similar to 4340 steel: Si 0.34, Cr 0.88, Mn 1.28, Ni 1.66 and Fe Alloy Structural Steel. Rockwell hardness of the cross section of down drag was HRC46.0 which equaled to 220 psi of the tensile strength.

The upper description and analysis was about the accident in 2004. The fracture characters in the failure case of 2005 were similar. The failure analysis showed that the failure mode of down drag, shear pins and other structures was overload fracture caused by excessive traction load. In addition, we found obvious joint gaps between aircraft, towbar, and tractor through field investigation, as shown in Fig. 7, which might have been the cause of the impulse load under conditions of tractor breaking or passing the trench of oil filler pipes.

3. Numerical analysis

The numerical analysis was taken Boeing 737-800 as the reference model to establish the dynamic model of aircraft towing system due to the lack of accurate data of Boeing 737-300. The basic hypothesis were as follow: the fuselage of aircraft and the body of towing tractor were assumed as rigidity; their masses were focused on their centers of gravity; the nose and the main landing gear were considered as absorb shock strikes; the aerodynamic force was not considered as the towing velocity was small. Models of aircraft, towbar, tractor, tire, and load were established in Adams, respectively. Then these sections were merged into a whole aircraft towing model, as shown in Fig. 8.

Fig. 9 showed the simplified clearance models of joint gaps between aircraft, towbar, and tractor. Clearances between aircraft and towbar were include three parts: the joint gap between towbar joint and axis pin of towing lug on the nose landing gear of aircraft was defined as Clearance1; joint gaps between towbar joint and bilateral baffles of towing lug were defined as Clearance2 and Clearance3. Analogously, joint gaps between towbar and tractor were divided into three parts: Clearance4, Clearance5, and Clearance6.

Clearances between aircraft, towbar and tractor were assumed as rule assembly clearances with the neglecting of the irregular clearance caused by normal wear. The relevant structural geometric parameters in Figs. 9 and 10 were shown in Table 1.

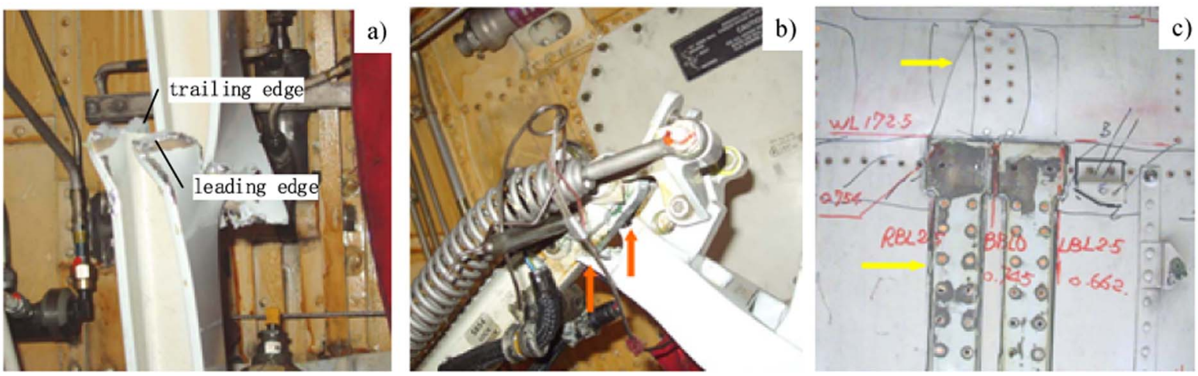

Fig. 2. Details of the fractured structures of nose landing gear: (a) down drag; (b) lock link; (c) aft bulkhead.