A Study on Towing Capacity with Deflated Tires of a Certain Type of Civil Aircraft

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Abstract: It is a very important ability whether civil aircraft allows the towing operation when tires flat in actual operating. Based on a certain type of regional aircraft, associating with ground load, ground equipment, landing gear structure, weight balance and maintenance engineering specialty etc, this paper studies the related airworthiness clauses of towing with deflated tires, analyzes the towing load of a certain type of aircraft and defines the scene when towing with deflated tires occur. Procedures of the normal towing and deflation towing are analyzed and similarities and differences of competing types of aircraft are also compared. On this basis, the actual towing ability of a certain type of aircraft is evaluated and more research on weight, safety factor of towbar and other aspects is conducted. Finally, the conclusion is provided that this type of aircraft has towing ability with single deflated tire by exceeding 60% of load requirement of the clause and being confirmed by strength evaluation.

Keywords: Airworthiness clause; Deflated tires; Towing load; A certain type of regional aircraft

1. Introduction
Aircraft towing is an operation of moving an aircraft by a ground tractor. According to the different ways of traction, aircraft towing can be divided into two categories: conventional towbar towing and towbarless towing. For a certain type of civil regional aircraft, it adopts the way of towbar towing. Under normal towing conditions, the aircraft is on the paved rigid pavement surface, and it is pulled forward or backward by the tow bar connected to the nose landing gear buffer pillar. The maximum allowable towing angle of the nose wheels is 102 ° to the left and right. Towing operation must ensure normal tire pressure. When the tire is deflated, it must be replaced before the towing operation can be performed.

2. Questions raised
In 2015, when the aircraft was in the course of demonstration operation, the airline proposed that there are other aircraft that allows at least one deflated tire when towing, which can greatly improve the convenience of operation, especially in special scenarios where the aircraft is fully loaded. If the towing operation is allowed with deflated tires, it can avoid the consequences of closing the runway and reduce the operating burden of the airline. Therefore, airline companies hope that the main manufacturer can analyze whether this type of aircraft allows towing operation with deflated tires.

3. Evaluation of towing ability with deflated tires
Four aspects of the towing ability with deflated tires are analyzed and explored in this chapter, those are towing design and airworthiness clauses related to towing with deflated tires, towing scenarios with
deflated tires that may occur, towing operation procedures with deflated tires of similar type of aircraft and towing ability of a certain type of aircraft.

3.1 Research on airworthiness clauses
a) 25.509 Towing loads
   According to CCAR25.509(a)[1], specifies the calculation method of towing loads for different aircraft weights. These loads must be applied at the towing fittings and must act parallel to the ground.
   For a certain type of regional aircraft, under normal tire inflation conditions, its towing load is given by
   \[ F_{TOW} = \left( \frac{6W_T + 204,100}{70} \right) g = 0.1526W_T g \]
   \[ \text{………………… (1)} \]
   Where \( W_T \) is the design ramp weight.
   According to CCAR25.509(d), specifies the towing loads for different towing points and towing directions. For this type of regional aircraft, the towing loads of the nose landing gear and the main landing gear in different directions are shown in Figure 1.

b) 25.511 Ground load: unsymmetrical loads on multiple-wheel units
   According to CCAR25.511(b)(1), stipulates the relevant considerations for wheel arrangements with deflated tires. For a multiple-wheel landing gear device, one of the tires must be considered to be deflated. For a landing gear device with four or more wheels, two of the critical tires must be considered to be deflated.
   For a certain type of regional aircraft, one deflated tire of its two-wheel landing gear device, that is, a single deflated tire should be considered.
   CCAR25.511(f) considers the effect of deflated tires on the structure and specifies corresponding towing load limits. For the case of one and two deflated tires, the towing load \( F_{TOW} \) must be 60% and 50% of the load prescribed, respectively.

3.2 Scenarios analysis
Towing scenarios with deflated tires are analyzed as follows.
a) When the aircraft is on the tarmac for pre-flight inspection, if the tire is deflated, it will not be released, and the tire should be replaced on the spot or towed to the nearby area.
   b) When the aircraft is on the runway and taxiway before take-off and after landing, if the tire deflates, the aircraft needs to be towed away from the runway and taxiway because there is no deflation taxing procedure.
   c) For maintenance purposes, move the aircraft with deflated tires (for example, from the boarding gate to the maintenance hangar).
d) Other scenarios where the aircraft may need to be moved when the tire is deflated.

3.3 Comparison of other types of aircraft

After consulting the manuals of other types of aircraft[2~5], the towing procedures with deflated tires for each type are obtained, as shown in Table 1.

Table 1. The towing procedures with deflated tires of related types of aircraft

| Aircraft type | Whether to allow towing operation with deflated tires | Tire deflation condition | Specific description of towing |
|---------------|------------------------------------------------------|--------------------------|-------------------------------|
| A320          | Yes                                                  | a) a maximum of one deflated tire on each landing gear. | Towing with nose landing gear and the maximum towing angle is +/- 10° |
|               |                                                      | b) one deflated tire on a main landing gear. | Towing with nose landing gear and the maximum towing angle is +/- 40° |
|               |                                                      | c) two deflated tires on one main landing gear (for four-wheel landing gear) | Towing with main landing gear and the towbar cannot be deflected |
| B737          | Yes                                                  | a) one deflated tire on the landing gear. | a) normal towing process b) minimum towing speed c) avoid sharp turns |
|               |                                                      | b) more than one deflated tires on each landing gear. | towed by main landing gear with cable, and the maximum angle of cable is +/- 30° |
| ERJ190        | Yes                                                  | at most one deflated tire on each landing gear (for four-wheel landing gear) | normal traction process, while a) ensuring no one on the plane b) the aircraft is as light as possible to reduce the load on the landing gear c) the maximum towing speed is 7km/h walking speed |
| CRJ200        | No                                                   | NA                       | All towing procedures require inflated tires. |

3.4 Towbar design conditions

According to references[6], the actual maximum towing load of a normal aircraft towing is obtained

\[ T_{\text{MAX}} = (0.06+\gamma) \times W_t \times 9.8 = 0.09W_t \times 9.8 \]  \hspace{1cm} (2)

Where \( \gamma \) is the maximum slope of the airport taxiway, taking 3%.

The actual maximum towing load ratio to the specified towing load \( F_{\text{TOW}} \) is given by

\[ \frac{T_{\text{MAX}}}{F_{\text{TOW}}} = 0.09W_t \times 9.8 / 0.1526W_t \times 9.8 = 0.59 \]  \hspace{1cm} (3)

In the design of the towbar of this type of aircraft, the shearing force of the safety bolt takes 0.8 times of the limiting towing load, that is, the safety factor of the towbar is designed to be 0.8. When there is starting acceleration, large turning or improper operation, the towing load for deflated tires is likely to
exceed 60% of the prescribed towing load. If it is between 60% -70%, the towbar safety pin will not be disconnected, which may damage the landing gear structure.

3.5 Evaluation of towing ability with deflated tires
This paper attempts to reduce the towing load by unloading the aircraft and increasing the corner limit. This type of aircraft has a minimum passenger load ratio of 7%. After conservative calculation, the load factor can only be adjusted to 0.645 and the turning angle is limited to 41° by the way of unloading weight. But this method cannot cover the safety factor of the towbar which is 0.8. The towing load limit cannot be fully released.

The "N" working condition when the tire is normally inflated is defined in this paper, as well as the most severe working condition when the single wheel deflates, that is, the "F" working condition that all three tires on the left side of the landing gear deflate, and the "G" working condition that all three tires on the right side of the landing gear deflate, as shown in Figure 2 and Figure 3.

"N" - Normal Tire:

**Figure 2.** Schematic diagram of normal tire inflation conditions

"F" / "G" - Tire Asymmetry (deflated tires) [25.511(c)]:

**Figure 3.** Schematic diagram of the most severe working condition of single-wheel deflation

Based on the above conditions, strength of the longitudinal (0°, 180°) and 45° of the nose and main landing gear is calculated when the towing load is 60% and 100% of fully inflated conditions applied to the nose landing gear with deflated tires, which demonstrates the actual carrying capacity of nose landing gear and main landing gear.

The nose landing gear was used as an example to define the main structural stress points of the nose landing gear. Among them, P1 and P2 are the connecting points of the main pillar of the landing gear and the fuselage, P3 and P4 are the connecting points of the landing gear resistance rods and the fuselage, and PA is the wheel pivot point, as shown in Figure 4.
Figure 4 Schematic diagram of the stress points on the structure of the nose landing gear of a certain type of aircraft

The comparative analysis of the strength of the nose landing gear is shown in Figure 5.

Through calculation and analysis, the result of the strength using 100% flat tire towing load with single deflated tire, comparing with the strength using 60% flat tire towing load, is given: the force $F_z$ of P1 and P2 structure of the nose landing gear has an increase of 4926N, which is 7.3%, the load of P3 and P4 structure has no change; the load of main structure has no change. After consulting the original strength data of the landing gear design, P1 and P2 have a strength margin of more than 10% in the structural design, which can completely cover the load increase caused by the tire deflation.

4. Conclusion
This type of aircraft can adopt the normal towing procedure in the case of single-wheel deflation, allowing towing operation of the nose landing gear with unlimited towing load. At the same time, the
towing speed is required to be as low as possible and a constant speed should be kept when performing the towing operation. Also, sharp turns should be avoided.

References

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