Load Analysis Of The Landing Gear Structure On The Grob G120TP-A

Benedictus Mardwianta[1], Muhammad Bimo Santoso[2], Abdul Haris Subarjo[3], Nurfi Ahmadi[4], Okto Dinaryanto[5] and Dedet Hermawan [6]

[1,2,3,4,5,6] Mechanical Engineering Department, Adisutjipto Institute of Aerospace Technology Yogyakarta, Indonesia

benedictusmardwianta@gmail.com*[1], ab.haris.79@gmail.com[3], okto.dinaryanto@itda.ac.id[5], dedetsetiabudi8@gmail.com[6]

Abstract. Abstract— The landing gear plays a role in supporting the weight of the aircraft while on the ground, and the characteristics of the landing gear vary according to the characteristics of the aircraft itself. The Grob G120TP-A aircraft utilizes Retractable Tricycle Landing Gear. With a three-wheeled structure, as a result, the aircraft is more stable when on the ground, and the landing gear must be capable of absorbing landing loads and navigating uneven terrain. To understand the limitations of the landing gear structure's capabilities for the Grob G120TP-A aircraft, a structural analysis is necessary. During the landing gear analysis phase, specific provisions have been formalized to analyze the weight of the landing gear structure for the Grob G120TP-A aircraft. The Grob G120TP-A aircraft has a center of gravity position in terms of percent MAC ($\bar{X}$TO) of 36.38% and ($\bar{Y}$TO) of 62.31%, with a center of gravity height of 1,420 m. The maximum static load for the main landing gear (MLG) is 45,686.79 N, and for the nose landing gear (NLG) is 54,631.66 N. The minimum static load for the MLG is 53,556.01 N. The dynamic load for the NLG is 91,340.38 N, and for the MLG is 82,395.51 N.

Keywords: landing gear, Grob G120TP-A aircraft, Mean Aerodynamic Chord, static load, dynamic load

1 Introduction

Landing gear plays a role in holding the weight of the aircraft while on the ground and the characteristics of different landing gears are adjusted to the characteristics of the aircraft itself. On the Grob G120TP-A aircraft, the landing gear class worn is "Retractable Tricycle Landing Gear". One nose landing gear and two main landing gear. With the tricycle structure, the aircraft is more normal when on the ground. The landing gear must be able to absorb landing loads and sturdy ground handling. In order to recognize the limits of the ability of landing gear structures for Grob G120TP-A aircraft, it is worth undergoing a shape analysis. Carry out a Final Project study with the head of the essay "Analysis of Landing Gear Load on XI'AN MA60 Aircraft"[1]. This

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research will be explained about ensuring loading on the runway according to WBM (weight and balance manual), MA60 on the functional expertise of landing gear according to AMM (Aircraft Maintenance Manual) MA60. In the analysis of the load effect of landing gear structures on MA60 aircraft, the use is in a theoretical way with calculations using the Mathcad 14 application. In his journal entitled "Aircraft Landing Gear Design: Principles and Practices: AIAA education series" [2] this research will explain that the maximum static load of the main landing gear must be calculated by the number of tires per sturt to obtain a single static wheel load. This journal entitled "Aircraft design A Systems Engineering Approach"[3] in this research wants to describe aircraft design with a systems engineering approach. Tricycle is the arrangement of landing gear at least many rear wheels of the aircraft closer to the center of gravity and support the weight of the fuselage and existing loads, as a result the main landing gear is taught. The 2 main gears are located at a distance commensurate with the center of gravity with the X axis and a distance aligned on the Y axis (left and right), as a result both receive similar loads. The carry out Final Project research with the head of the essay "Static Analysis of the Strength of Fitting Structures on Landing Gear on N-219 Aircraft"[4]. In this research will be explained about the capacity of aircraft structures. The structure of the aircraft must be made sturdy so that it can withstand the force obtained throughout the middle within tolerable use limits. Meanwhile, transformation (deformation) can be defined as a transformation that is middle in its elasticity region, but will result in permanent transformation caused by repeated force treatment on the structure, resulting in permanent transformation and foundering of the structure.

1.1 Landing Gear Structure Load On Grob G120TP-A Aircraft

The landing gear consists of 3 landing gears that have landing gear that can be pulled in in a full way, operated by hydraulic and supervised by electricity, the main landing gear can be pulled into the wing structure while the nose landing gear is pulled back into the fuselage structure. The Grob G120TP-A aircraft is the result of further development of the previously existing aircraft is the G120 which has certification in the use of piston engines and 3 propeller blades. This development uses a form that already has with some orientations related to engine and propeller type abnormalities. Grob G120TP-A aircraft is an aircraft with 2 reclining places and has a small wing (low wing) with a fuselage arranged from plastic reinforced fiberglass.

Fig. 1. Grob G120TP-A aircraft

Table 1. AIRCRAFT GENERAL

No	*Aircraft Manufactur*	Grub *Aircraft* AG,86874Tuessenhausen-Mattsies
1	*Type of Aircraft*	Pesawat Utility
2	*Length*	10,188m
3	*Wing Span*	10,312m
4	*Height*	2,620m
5	*Empty Weight*	2214lbs (9848,36N)
6	*Max T/O Weight*	3285lbs (14612,40N)
7	*Zero Fuel Weight*	2965lbs (13188,97N)
8	*Wheel Base*	6,13 f.t / 1,869m
9	*Wheel Thread*	7,94 ft / 2,420m
10	*Min Prop Height*	1,2 ft / 0,37m
11	Kecepatan	172KIAS
12	*Load Limit*	+ 6,0 ≈ -4 [G]
13	*Max Landing Weight*	3175lbs (14123,10N)
14	*Max Ground Weight*	3285lbs (14612,40N)
15	*Service Ceilling*	35,000ft

Table 2. ENGINE TYPE

No	*Engine Type*	*Turbo-Propeller, Rolls-Royce Corporation. Model No. 250-B17F AVCO LYCOMING,*
		MODELAEOI-5400D4D5
1	*Max Rating*	2000 + 30 rpm, 450 SHP
2	*Combustion Chambers*	*Annular*
3	*Compression Ratio*	9:01
4	*Prop Shaft Rotation*	*Clockwise*
5	*Prop Shaft Coupling*	*Flange*
6	*Reduction Gear*	*Planetary Type, Gear Ratio*
7	*Engine Diameter*	18,29 in
8	*Engine Length*	70,5 in
9	*Dry Weight*	212lbs (943,02N)
10	Total *Weight*	997,7lbs (4437,99N)
11	*Power Turbin Rating*	33.235 rpm

Table 3. LANDING GEAR

No	*Fluid System*	MIL-H-5606 Hydraulic Fluid
1	*Hydraulic Pressure*	3000 PSI
2	*NLG Strut Pressure*	80 PSI
3	*MLG Pressure*	140 PSI
4	*MLG Tire Pressure*	43.3 PSI

5	*NLG Tire Pressure*	36 PSI
6	*Tire Manufacture*	*GoodYear*

The Grob G120TP-A aircraft uses a type of landing tricycle / 3 wheels that operate as landing gear, arranged in 3 techniques. So sequence 3 has one wheel in front which is said nose landing gear and 2 wheels behind which is said to be the main landing gear.

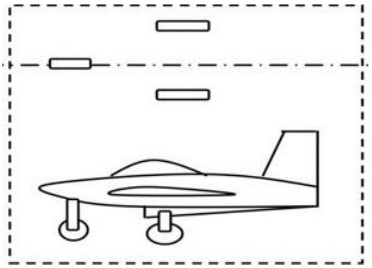

Fig. 2. Tricycle Type

The nose landing gear operated by hydraulic is installed in the landing gear wheel room, this part is folded back into the wheel chamber by the nose landing gear actuator and is located in a locked situation by mechanical means by the hook when the landing gear control handle is used in the situation, the nose landing gear door, and opened and closed when the landing gear is stretched and folded [5].

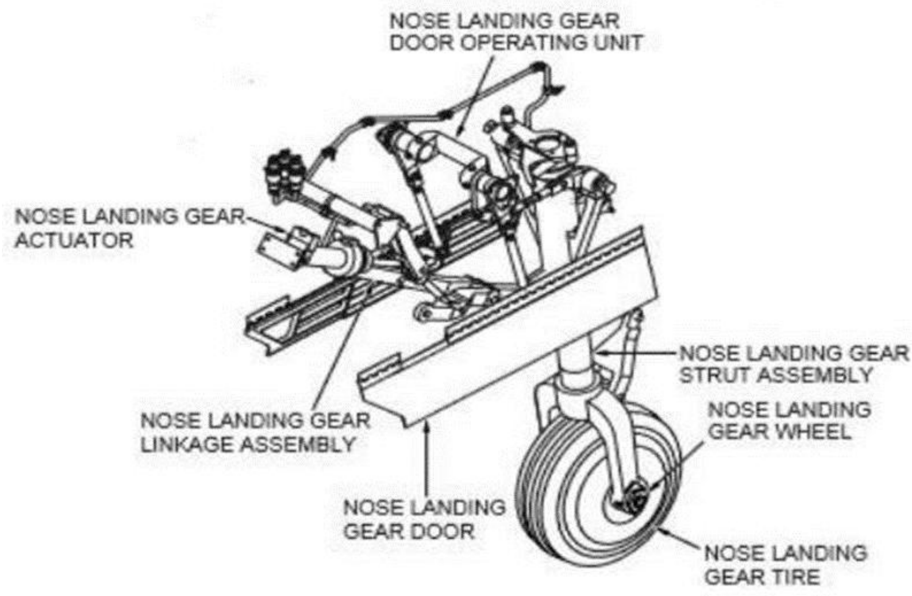

Fig. 3. Nose Landing Gear

The main landing gear operates in a hydraulic way, the main landing gear is installed on the main landing gear bay (wheel room), if the landing gear control handle is in the up position, the main landing gear door actuator will operate to open the inboard door, after the main landing gear is folded, the doors will be closed, when the landing gear is fully rolled the component will be located in a locked position mechanically by the hook and inboard door and in the locked position by the internal lock.

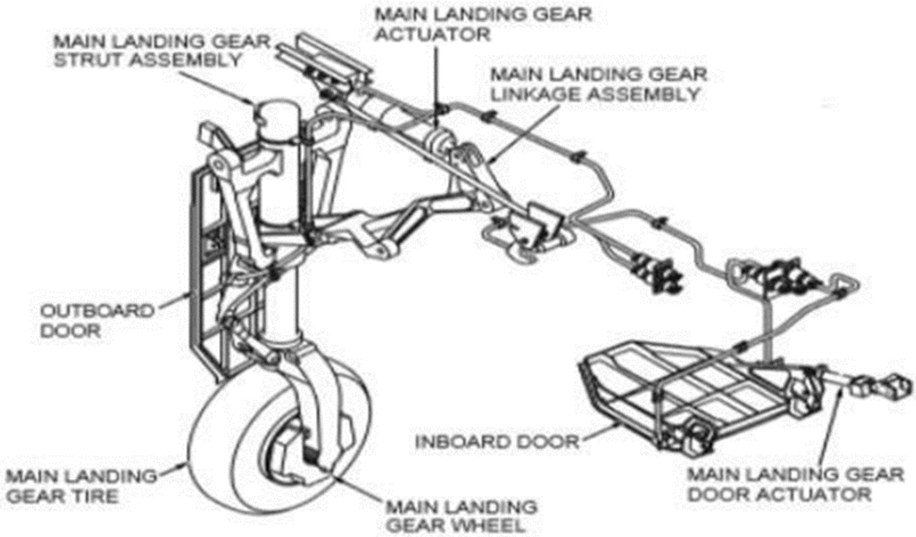

Fig. 4. Main Landing Gear Components

Aircraft are capable of being on the ground or in the air, almost every component of the landing gear gets loaded. Where the load is caused due to the force of attraction of the earth, aerodynamics or inertia. some aircraft positions during loading include the aircraft in a non-operational situation (static state), Taxing, Take-off, level flight, and landing. Landing gear loading also takes place in vertical load and horizontal load situations. In determining the center of gravity of the aircraft, the distance between the tips of the front and rear wings, measured parallel to the natural air bow above the wing, is known as a chord. When the main edge and trailing edge are aligned, the chord of the wing is stable along the length of the wing. Most profitable transport aircraft have tapered wings and clean with the result that the wing area changes throughout the totality of its length. The wing field is at least large where it will meet the body at the wing source and shrink towards the end. The average length of chords is known as the average aerodynamic chord (MAC)[6]. In large aircraft, the center of separation of the earth's tensile force and the center of the earth's attraction are actually often claimed in percent MAC. In determining the initial position of the center of gravity, it is based on design regulations consisting of knowing the length of the MAC (Mean aerodynamic chord) to decide the position of the center of gravity on the mean aerodynamic chord. In determining the length of the MAC it is necessary to know the typical wing, examples of perspective or shape (straight wing or half wing).

2 METHODOLOGY

The methodology used is in accordance with the flowchart below.

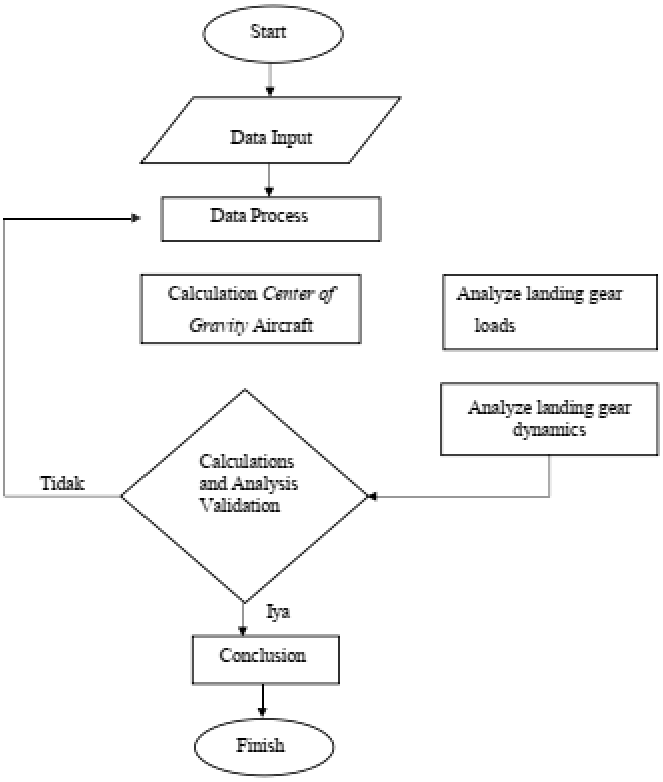

Fig. 5. Flowchart

In this research, several levels of research techniques were carried out from data cultivation to how to verify details and analyze data. In completing this research using several methods of data collection, including: Observation Method. This technique is a procedure for collecting data and data by observation and recording aspects and subjects to be analyzed. Library Methods. The library method is the collection of data sourced from related reference libraries and also the collection of data from internet intermediaries. Interview Method. The question and answer method is data collection with speech answer questions or recorded directly or with other communication equipment that has skills and experts in the aspects to be studied.

Determining the position of the center of gravity of the aircraft is carried out by the following methods: 1. Determining the mass of the aircraft according to the situation of the aircraft. In this determination is taken into account the mass of the aircraft for take-off. Formulated as follows

$$G_{OEW} = G_{MEW} + G_{PW} \tag{1}$$

$$G_{WTO} = G_{OEW} + G_{FW} \tag{2}$$

$$X_T = \frac{(G_{OEW} \cdot X_{OEW}) + (G_{PW} \cdot X_{PW}) + (G_{FW} \cdot X_{FW})}{G_{WTO}} \quad (3)$$

$$Y_T = \frac{(G_{OEW} \cdot Y_{OEW}) + (G_{PW} \cdot Y_{PW}) + (G_{FW} \cdot Y_{FW})}{G_{WTO}} \quad (4)$$

$$X_{TO} = (X_T - X_0) \cdot \cos 3° + (Y_0 - Y_T) \cdot \sin 3° \quad (5)$$

$$Y_{TO} = (Y_0 - Y_T) \cdot \cos 3° + (X_T - X_0) \cdot \sin 3° \quad (6)$$

$$\overline{X_{TO}} = \frac{X_{TO}}{MAC} \cdot 100\% \ (MAC) \quad (7)$$

$$\overline{Y_{TO}} = \frac{Y_{TO}}{MAC} \cdot 100\% \ (MAC) \quad (8)$$

$$H_{cg} = \Delta H_{clear} + \frac{D_{propeller}}{2} \quad (9)$$

$$H_{NLG} = H_{cg} + \frac{D_{fuselage}}{2} \quad (10)$$

$$t_w = \left(\frac{t}{c}\right)_{max} . \bar{c} \quad (11)$$

$$H_{LG\ MAIN} = H_{CG} - \frac{t_W}{2} \quad (12)$$

The load on the landing gear takes place into 2 types, namely static loads and dynamic loads. Previously, we wanted to calculate the distance from the two centers of gravity. Static load is the weight that operates when the aircraft is in a calm situation and does not switch during the loading period for take-off.

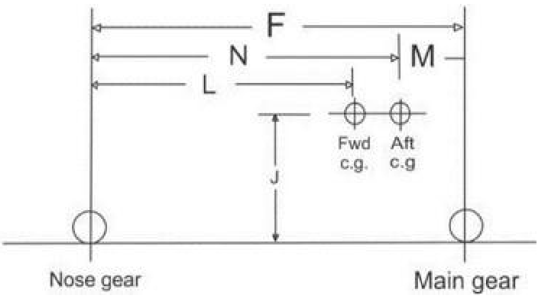

Fig. 6. Landing Gear Load Determination

The determination of landing gear loading above proves to ensure the distance between the nose landing gear to the forward, and the main landing gear to aft.

$$P_m = \frac{G_{WTO} \cdot g \cdot (F - M)}{n^2 \cdot F} \quad (13)$$

$$P_{ns\ max} = \frac{G_{WTO} \cdot g \cdot (F - L)}{F} \tag{14}$$

$$P_{ns\ min} = \frac{G_{WTO} \cdot g \cdot (F - N)}{F} \tag{15}$$

$$P_{n\ dyn} = P_{ns\ max} + \frac{a_x \cdot H_{cg} + (G_{WTO} \cdot g)}{g \cdot F} \tag{16}$$

$$P_{n\ dyn} = P_m + \frac{a_x \cdot H_{cg} + (G_{WTO} \cdot g)}{g \cdot F} \tag{17}$$

Analyze the rotational end of the aircraft. The end of the rotation or turning angle is formed by the landing gear to carry out taxing turns on the bow line. Analyzing the end of rotation of the aircraft to understand whether when the landing gear faces loading is complementing the turning angle skills it can perform.

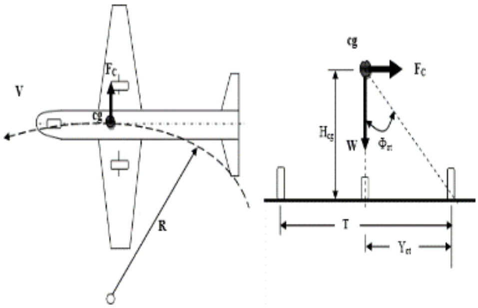

Fig. 7. Turning Angle

$$F_c = m \cdot \frac{v^2}{R} \tag{18}$$

$$\vartheta_{ot} = \tan^{-1} \frac{F_c}{m.g} \tag{19}$$

To understand the major transformations of force on the shock strut when facing changes in the point of gravity that affect the movement of the action of the piston rod that operates to overcome or dampen when receiving a load

$$A_{piston} = \frac{P_{m\ max}}{P_2} \tag{20}$$

$$F_{total} = P \cdot A \tag{21}$$

Analysis of the dynamics analyzed to understand the magnitude of the proficiency of the impact landing load effect absorber obtained by the strut landing gear.

$$E_t = \frac{0{,}5 \cdot (W_L) \cdot (W_t)^2}{g} \tag{22}$$

$$P_{n\ dyn\ tire} = \frac{(W_{TO} \cdot g)\left\{M + \left(\frac{a_x}{g}\right) \cdot (H_{cg})\right\}}{\eta_t \cdot (M+N)} \quad (23)$$

$$S_s = \frac{\left[\left\{\frac{0{,}5 \cdot \left(\frac{P_{n\ max}}{g}\right) \cdot (W_t)^2}{n_s \cdot P_{n\ dyn\ tire} \cdot N_g}\right\} - \eta_t \cdot S_t\right]}{\eta_s} \quad (24)$$

$$S_s = \frac{\left[\left\{\frac{0{,}5 \cdot (W_L) \cdot (W_t)^2}{n_s \cdot P_m \cdot N_g}\right\} - \eta_t \cdot S_t\right]}{\eta_s} \quad (25)$$

Grob G120TP-A aircraft is a type of small-wing Utility Aerobic army aircraft with the use of piston engines and 3 propeller blades made by Tussenhausen-Mattsies, in Germany.

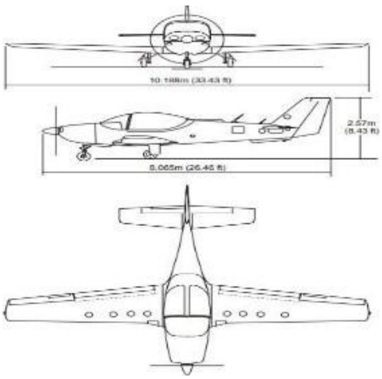

Fig. 8. Grob G120TP-A Dimension

Table 4. GROB G120TP-A DIMENSION

No	Komponen	Besaran (SI)
1	*Wing Span (expect fairing)*	10,312 m
2	*Length (expect fairing)*	3,880 m
3	*Flap span 0,5*	2,000 m
4	*Aileron span 0,5*	1,853 m
5	*Maximum width*	1,303 m
6	*Propeller*	2,100 m
7	*Height overall*	2,620 m
8	*Length overall (include spinner)*	8,424 m
9	*Landing gear wheel base*	1,854 m
10	*Minimum propeller height*	0,37 m
11	Maximum landing distance and	2,329 m
12	*Landing gear whell tread*	2,243 m

3 ANALYSIS AND DISCUSSION

The analysis uses the detailed instruction manual to be carried out regarding the load analysis of the landing gear structure on the Grob G120TP-A aircraft [7]. As an outline of the analysis method as follows, determine the loading for the aircraft, determine the position of the center of gravity of the aircraft, determine the loading on the landing gear, and analyze the landing gear damping expertise. Below is table 5 about Aircraft Report to facilitate the use of data, where calculations will be entered on the load of the Grob G120TP-A aircraft as follows:

Table 5. AIRCRAFT GENERAL REPORT GROB G120TP-A

No	Komponen	Besaran
1	Gaya percepatan gravitasi bumi X_{cg}	9,807 m/s^2
2	Posisi GOEW pada koordinat X_{cg}	4,156 m
3	Posisi pilot weight pada koordinat X_{cg}	1,085 m
4	Posisi fuel weight pada koordinat c.g X_{cg}	2,500 m
5	Posisi operational empty weight pada koordinat Y_{cg}	1,672 m
6	Posisi GPW pada koordinat Y_{cg}	1,538 m
7	Posisi GFW pada koordinat Y_{cg}	0,716 m
8	Jarak antara datum dan leading edge	3,540 m
9	Jarak antara X aircraft struktur	2,560 m
10	Mean Aerodynamic Chord (MAC)	1,388 m
11	Diameter propeller	2,10 m
12	Jarak propeller dengan landasan	0,37 m
13	Diameter fuselage	2,27 m
14	Airfoil thicknes to chord ratio	8 %
15	Bagian yang pertama kali menyentuh landasan / Number	2
	Of Strut (jumlah peredam kejut)	
16	Wheel base	1,854 m
17	Laju penurunan	4,478 m
18	Radius	30 m
19	Beban statik per-strut 1	80 PSI
20	Beban statik per-strut 2	140 PSI
21	Landing weight	14123,10 N
22	Touchdown rate span 0,5	2,500 m
23	Defleksi ban	4,487 m
24	Load factor	2 G
25	Faktor efisiensi untuk ban / Number Of Tire (jumlah)	20
26	Kecepatan pesawat selama di ground	10,28 m/s

27	Pilot weight (2)	2157, 463 N

1. Determining the Center of Gravity of the Aircraft

According to Table.5 Grob G120TP-A Aircraft Weight, namely the maximum allowable weight on Grob G120TP-A aircraft has been determined first, then the load is used to estimate the operational empty weight mass load and take-off weight mass so that the calculation is as follows:

Table 6. GROB G120TP-A AIRCRAFT WEIGHT

No	Komponen	Besaran (lb)	Berat (N)
1	*Weight empty*	2,214 lbs	9848,362 N
2	*Max. take-off weight*	3,285 lbs	14612,408 N
3	*Max. landing weight*	3,175 lbs	14123,103 N
4	*Max. ground weight*	3,285 lbs	14612,408 N
5	*Total fuel tank capacity*	623.25 lbs	2772,354 N

Calculation of the mass of an operational empty weight aircraft is

$G_{OEW} = G_{MEW} + G_{PW}$

$= 9848{,}362\ \text{N} + 2157{,}463\ \text{N}$

$= 12005{,}825\ \text{N}$

Calculation of aircraft mass for take off weight is

$G_{WTO} = G_{OEW} + G_{FW} = 14163{,}288\ \text{N}$

$= 12005{,}825 + 2772{,}354\ \text{N}$

$= 14778{,}179\ \text{N}$

MAC (Mean Aerodynamic Chord) can be observed in fig. 8, which is a representation of 2 widths of all wings. Weight distribution across the wing can be reduced as a single and fleeting lift around the MAC's aerodynamic center. Therefore, not only the length but also the position of the MAC often works. In a certain way, the position of the center of earth attraction (CG) of an average plane object is measured relative to the MAC, as a percentage of the distance from the front end of the MAC to the CG (Center of Gravity) with respect to the MAC itself. Below is calculated to find c.g XT and also c.g YT for aircraft coordinates as follows

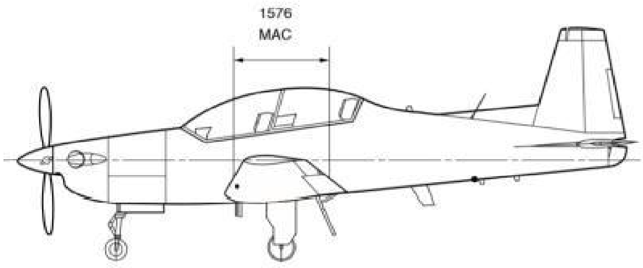

Fig. 9. Mean Aerodynamic Chord (MAC) Aircraft Grob G120TP-A

Calculation of CG (center of gravity) XT for take-off weight (WTO) according to aircraft coordinates is

$$X_T = \frac{(G_{OEW} \cdot X_{OEW}) + (G_{PW} \cdot X_{PW}) + (G_{FW} \cdot X_{FW})}{G_{WTO}}$$
$$= \frac{(12005{,}825\ N \cdot 4{,}156\ m) + (2157{,}463\ N \cdot 1{,}085\ m) + (2778{,}354\ N \cdot 2{,}500\ m)}{14778{,}179\ N}$$
$$= 4{,}003\ \text{m}$$

The calculation of CG (center of gravity) YT for take-off weight (WTO) begins at the coordinates of the aircraft is

$$Y_T = \frac{(G_{OEW} \cdot Y_{OEW}) + (G_{PW} \cdot Y_{PW}) + (G_{FW} \cdot Y_{FW})}{G_{WTO}}$$
$$= \frac{(12005{,}825\ N \cdot 1{,}672\ m) + (2157{,}463\ N \cdot 1{,}538\ m) + (2778{,}354\ N \cdot 0{,}716\ m)}{14778{,}179\ N}$$
$$= 1{,}717\ \text{m}$$

Calculation of the distance between the center of gravity to the leading edge along the Mean Aerodynamic Chord (XTO) is

$$X_{TO} = (X_T - X_0) \cdot \cos 3° + (Y_0 - Y_T) \cdot \sin 3°$$
$$= (4{,}003\text{m} - 3{,}540\text{m}).\cos 3° + (2{,}560\text{m} - 1{,}717\text{m}).\sin 3°$$
$$= 0{,}505\ \text{m}$$

The distance between the center of gravity to the leading edge along the Mean Aerodynamic Chord (YTO) is

$$Y_{TO} = (Y_0 - Y_T) \cdot \cos 3° + (X_T - X_0) \cdot \sin 3°$$
$$= (2{,}560\text{m} - 1{,}717\text{m}).\cos 3^0 + (4{,}003\text{m} - 3{,}540\text{m}).\sin 3°$$
$$= 0{,}865\ \text{m}$$

The calculation of the weight of the aircraft, operational empty weight and also the position of the center of gravity is determined to load at least the size of the aircraft situation for take-off weight. Based on the principle of the calculation above, it is known that the weight of the aircraft for empty weight is 12005.825 N and for take-off weight is 14778.179 N. From the manufacture of Grob G120TP-A aircraft aircraft takes a decision on the coordinate point or point 0 of the Grob G120TP-A aircraft starting from the nose landing gear as a result it is known that the position of the center of gravity of the aircraft for XT coordinates is 4.003 m and YT coordinates are 1.717 m. The distance between the center of gravity to the end of the landing edge along the MAC (XTO) is 0.505 m. the vertical distance between the center of gravity and the MAC (YTO) is 0.865 m. For determination of the position of the center of gravity in percent mean aerodynamic chord ($\overline{X}$TO) is 36.38% MAC and ($\overline{Y}$TO) is 62.31%, with the height of the center of gravity is 1.420 m. Conversely, the height of the nose landing gear is 0.285 m. For the height of the main landing gear, the thickness of the chord wing for aircraft in its class was previously determined as a result of which the wing airfoil for the Grob G120TP-A aircraft was 0.111 m with a chord thickness of 8%, then calculated the thickness or thickness of the aircraft wing was 1.364 m.

The load on the landing gear is 2 wheels consisting of 2 tires, as a result the load is distributed on each of the tires, including the maximum static load of the main landing gear is 45686.79 N. The maximum static load of the nose landing gear is 54631.66 N. The minimum static load of the main landing gear is 53556.01 N. The dynamic load on the nose landing gear is 91340.38 N. The dynamic load on the main landing gear is 82395.51 N.

For the analysis of the peak rotation of the aircraft, the centrifugal force released within a rotation radius of 30 m is 52159.139 N. The peak rotation of the aircraft is 0.35 degrees of inclination position at the time of the aircraft rotation within a radius of 30 m.

4 CONCLUSION

The calculation of the aircraft's operational empty weight load and also the position of the center of gravity is determined to load at least the size of the aircraft atmosphere for take-off weight. Based on the principle of the details above, it is known: The aircraft load for empty weight is 12005.825 N and take off weight is 14778.179 N.

From the manufacturer of the Grob G120TP-A aircraft, the first coordinate point or point 0 of the Grob G120TP-A aircraft starts from the nose landing gear, as a result it is known that the position of the center of grafity of the aircraft for XT coordinates is 4.003 m and YT coordinates are 1.717 m. The distance between the center of gravity to the end of the landing edge along the MAC (XTO) is 0.505 m. The vertical distance between the center of gravity and the MAC (YTO) is 0.865 m. To determine the position of the center of gravity in percent mean aerodynamic chord ($\overline{X}$TO) is 36.38% MAC and ($\overline{Y}$TO) is 62.31%, with the height of the center of gravity is 1.420 m.

As for the height of the nose landing gear is 0.285 m. For the height of the main landing gear, the thickness of the chord wing was previously determined according to the aircraft in its class, as a result the wing airfoil for the Grob G120TP-A aircraft was 0.111 m with a chord thickness of 8%, then the thickness and thickness of the aircraft wing was taken into account, which was 1.364 m. The maximum loading on the nose landing gear and main landing gear on the load analysis of the landing gear structure on the Grob G120TP-A aircraft in ground conditions is: aircraft weight for take-off weight 14778.179 N. The results of the loading analysis on the landing gear of the Grob G120TP-A aircraft in static and dynamic conditions are: The maximum static load on the main landing gear is 45686.79 N.

Maximum static load on nose landing gear 54631.66 N. Minimal static load on nose landing gear 53556.01 N. Dynamic load on nose landing gear 91340.38 N. Dynamic load on main landing gear 82395.51 N.

The results of the dynamic analysis received by the strut landing gear due to the impact landing load, damping capability. As follows The weight of the aircraft at landing was 14123,103 N, as a result the kinetic energy immersed by the aircraft when touch down was 4500.3 joules. The maximum dynamic load of the tire landing gear reviewed for braking is 90241.32 N. The stroke length for the shock strut nose landing gear at touchdown or touching the runway is -44.77 m.

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