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A Four-Seat Light Airplane Design

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Abstract

Malaysia produces two-seat light airplane through two firms, SME Aerospace Sdn. Bhd. and Eagle Aircraft Sdn. Bhd. As these airplanes are limited to recreational, flight training and acrobatic activities, a four-seat airplane was proposed. Financed by the Ministry of Science and Technology, a research team was formed.

The new airplane was designed based on the SME two-seat airplane, the MD3-160 using Professor Jan Roskam methodology. In the process, AutoCAD® and General Aviation Computer Aided Design® software were utilized.

Preliminary results indicated that the designed four-seat airplane has better performance than the original two-seat airplane and at the same time staying very competitive in comparison to others in its class. The airplane also is very stable and possessing the Level 1 flying qualities.

Introduction

Two companies are currently producing light airplanes in Malaysia. SME Aviation Sdn. Bhd. manufactures MD3-160; an all-metal construction airplane while Eagle Aircraft (M) Sdn. Bhd. manufactures Eagle 150B, an all-composite construction airplane [1-2]. Both airplanes are two-seat airplanes and their operations are limited to recreational, flight training and acrobatic activities.

Although these airplanes are manufactured locally, their designs originated from Austria and Australia respectively. To transfer the airplanes design technologies, a team of researcher from Universiti Teknologi Malaysia (UTM) was formed. Finance by Ministry of Science and Technology, the team proposed designing a four-seat airplane from one of these two-seat airplane [3]. The four-seat airplane was proposed due to its ability to carry more payloads and having longer flying range. Furthermore, four-seat airplane has the biggest market share in light airplane sales. In the year 2001, for an example, General Aviation Manufacturer Association (GAMA) reported that three to five seat airplanes held 55% of market share [4].

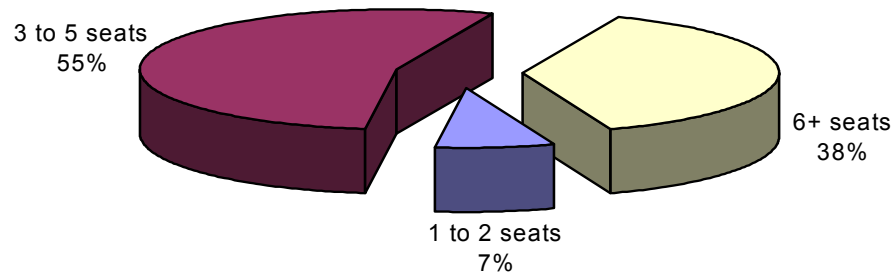


Figure 1. Market share of light airplane in year 2001 [4]

DESIGN CONCEPT AND METHODOLOGY

Named RGS P4-180, the designed four-seat airplane is based on the SME MD3-160 airplane. The MD3-160 was selected due to:

- Accessibility to original documents and references.
- Manufacturer's willingness to participate in the research project.

Conceptual design process of the four-seat airplane is shown in Figure 2.

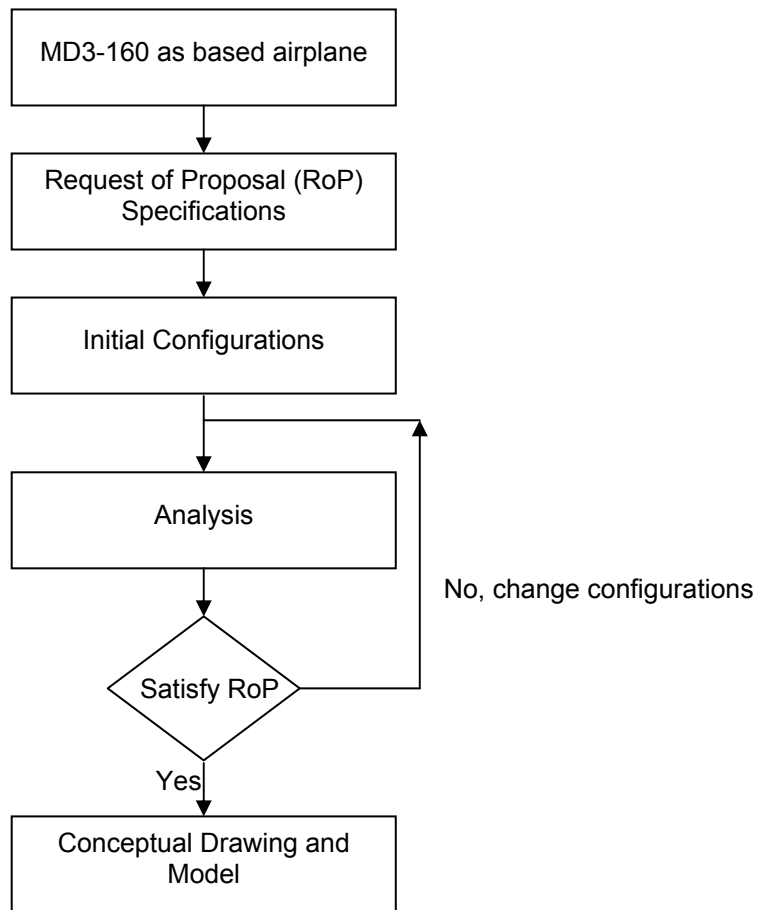


Figure 2. Conceptual design flow chart

Based on literature review and market survey, a Request of Proposal for RGS P4-180 was drafted and is tabulated in Table 1.

Table 1. Request of Proposal for RGS P4-180

Parameters	Value
Type	Light airplane
Category	Utility
Power plant	Propeller driven single engine
Capacity	4 including pilot
Range	1,000 km (540 n. mile)
Cruise speed	228 km/hr (123 kts)
Service ceiling	3,048 m (10,000 ft)
Cabin type	Unpressurized

However, the design constraints require RGS P4-180 to use as many MD3-160 parts as possible to reduce production cost.

Initial RGS P4-180 configurations require these modifications to be implemented on based airplane;

→ *Bigger engine horsepower and larger fuel tank*

Since RGS P4-180 is heavier and has better performance requirements, it must be equipped with bigger engine horsepower and larger fuel tank. The fuel tank will be placed inside the airplane wing.

→ *Low wing configuration*

Low wing configuration will free the cabin area from wing structure. It also allows the airplane main landing gears to be placed under the wing.

- *New cabin and engine compartment design*
Due to its additional passengers, RGS P4-180 requires longer cabin. Its engine compartment also has to be redesigned. These cause the airplane to have longer fuselage. Its rear fuselage however will use those from MD3-160.
- *New landing gear design*
As RGS P4-180 carries more weight, having longer fuselage and low wing configuration, new landing gear design is required.
- *New design on airplane stability and control system*
The different configuration of RGS P4-180 requires new design on its stability and control system.

Initial configurations were analyzed using Roskam's Methods [5-13]. The analyses performed were:

- Weight
- Aerodynamics
- Propulsion
- Sizes
- Performance
- Stability and control
- Landing gear configuration

To assist the analysis process, a window based software called General Aviation Computer Aided Design; GA-CADD[®] was used. Divided in modules, the software allows user to analyze a design, make changes and rapidly determine the effect of the changes to the airplane design, while working within regulatory constraints [14]. The software, however, does not support landing gear design. Thus, the landing gear analysis has to be done manually. Analysis process is iterated until results satisfy the RGS P4-180 Request of Proposal requirements.

Throughout the design process, airplane drawings were drawn using AutoCAD[®] software. The aircraft drawings were updated as results from the analysis process change. A scale model of the airplane was built to confirm the design concept.

RESULTS AND DISCUSSION

A. Configuration

The RGS P4-180 has a longer fuselage with low wing configuration. Its cabin is extended 0.87 meter forward; where the previous front seats position become rear seats. The airplane uses the MD3-160 wing with main landing gear under the wing. The wing structure however has to be strengthened due to higher wing loading and load from main landing gear. Despite its low wing configuration, its height is maintained. It also has its original tail section. Access to the airplane cabin is through two side doors. Its nose and main landing gear locations and heights satisfy both over-turn and tip-over criteria. Comparison of the RGS P4-180 configurations to its based airplane is given in Table 2.

Table 2. Comparison of the based and designed airplane configurations

Dimensions	MD3-160 (based)	RGS P4-180 (design)
Overall length	7.10 m	7.97 m
Height	2.92 m	2.92 m
Landing gear track	2.05 m	2.37 m
Landing gear wheelbase	1.55 m	2.50 m
Wing area	15.00 m ²	15.00 m ²
Wing span	10.00 m	10.00 m
Wing chord	1.50 m	1.50 m
Wing aspect ratio	6.67	6.67
Horizontal tail span	3.00 m	3.00 m
Cabin access	sliding canopy	2 side doors

The RGS P4-180 3-views drawing and conceptual picture are depicted in Figure 3 and Figure 4.

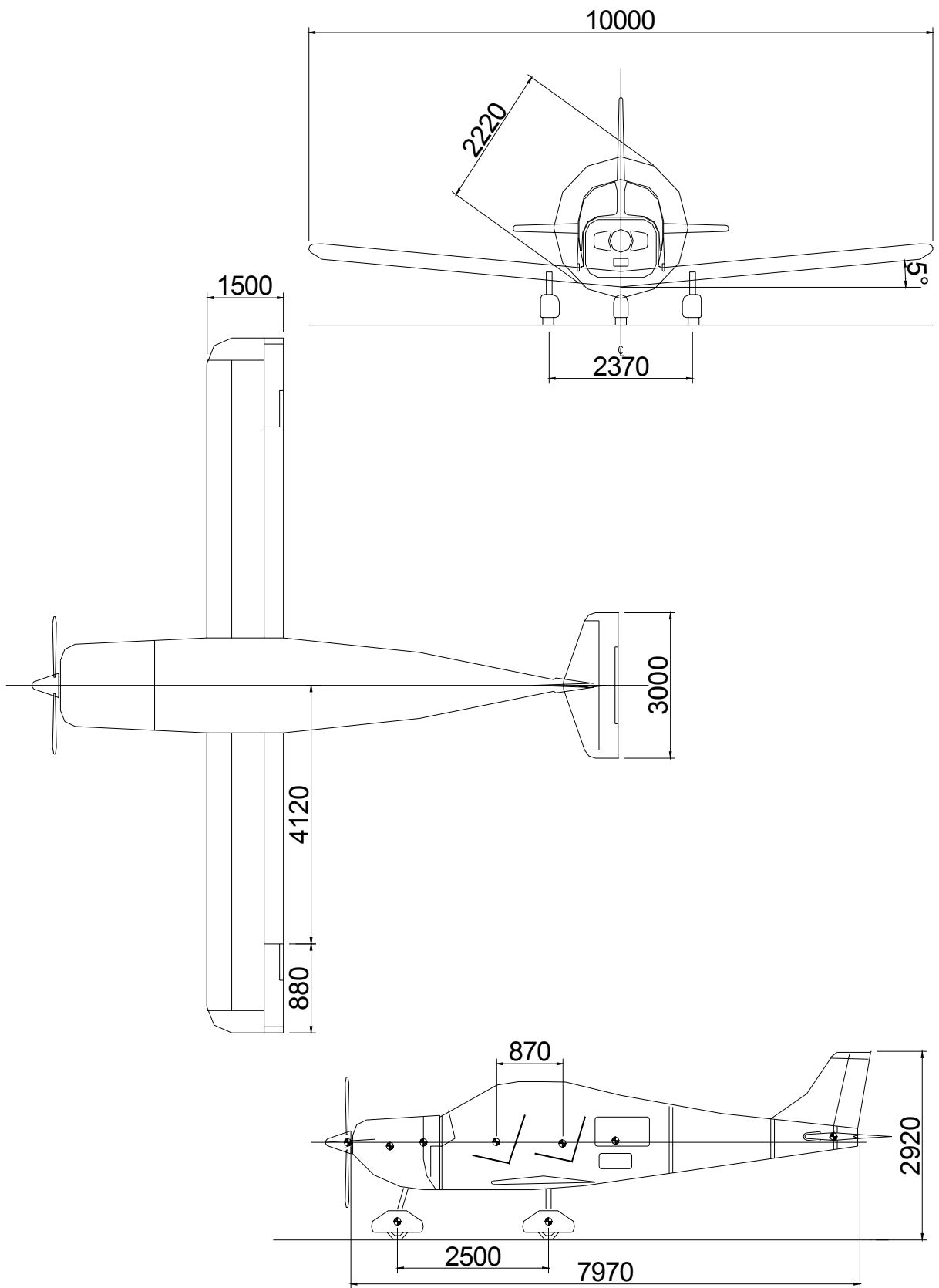


Figure 3: The RGS P4-180 3-views drawing with dimension in mm



Figure 4. The RGS P4-180 conceptual picture

B. Performance

Performance results from GA-CAD[®] software are tabulated in Table 3.

Table 3. Airplane performance

Parameters	RGS P4-180	L-17 Navion [15]	Piper PA28R Cherokee Arrow [16]	Cessna 182 Skylane [17]
Weight (N)	11,770	13,116	11,125	11,380
Engine power (hp)	180	185	180	230
Wing Loading (N/m ²)	785	767	783	702
Power Loading (N/hp)	65.39	70.93	61.80	49.44
Cruising speed (km/hr)	275	241	260	253
Initial rate of climb (m/min)	332	N/A	267	366
Service Ceiling (m)	5,500	3,353	4,572	6,096
Range (km)	1,033	1,127	1,600	1,078

As shown in Table 3, the RGS P4-180 performance not only surpasses the design requirements, but it is also competitive compares to other airplane with similar weight and horsepower. The airplane has high wing loading and power loading. A 180 horsepower engine with two blades fixed pitch is selected for the airplane. With better aerodynamics, it is able to cruise and climb fast. The airplane has a service ceiling of 5,500 meter above mean sea level and a flying range of 1,033 km. The airplane will have better performance if its airframe wing loading and power loading is reduced.

C. Stability

Placing the pilot and the front passenger forward while keeping the wing at its original position moves the airplane center of gravity to 18% of the wing aerodynamics chord from its original 20%. This increases the airplane static margin and improves its response. The airplane longitudinal and lateral dynamic stability characteristics during cruise from GA-CAD[®] software are tabulated in Table 4.

Although there is no modification on the airplane tail, results show that the RGS P4-180 is still statically and dynamically stable in both longitudinal and lateral motions. As shown in Table 4, the airplane stability characteristics are similar to those of its competitors. Moreover, the airplane satisfies Level 1 Flying Quality requirement in both longitudinal and lateral motions while cruising.

Table 4. Airplane dynamic stability at cruise

Parameters	RGS P4-180	L-17 Navion [18]	Piper PA28R Cherokee Arrow [19]	Cessna 182 Skylane [20]	Level 1 Flying Quality Limit [21]
<i>Phugiod Mode</i>					
Damping ratio, ζ	0.1809	0.0769	0.0865	0.1289	$\zeta > 0.04$
Natural freq., ω (rad/s)	0.1659	0.2146	0.2867	0.1711	
<i>Short Period Mode</i>					
Damping ratio, ζ	0.7644	0.6951	0.4881	0.8442	$0.3 < \zeta < 2.0$
Natural freq., ω (rad/)	4.3172	3.5064	4.5097	5.2707	
<i>Dutch Roll Mode</i>					
Damping ratio, ζ	0.1908	0.2040	0.0965	0.2066	$\zeta > 0.08$
Natural freq., ω (rad/s)	2.7466	2.3833	0.4767	3.2448	$\omega > 0.4$
<i>Rolling Mode</i>					
Time constant, τ (sec)	0.177	0.1186	0.1807	0.0769	$\tau < 1.4$
<i>Spiral Mode</i>					
Time constant, τ (sec)	56.849	112.36	43.1035	55.866	$\tau > 20$

CONCLUSION

The MD3-160 design technology was transferred to Malaysia in this research. Designing a four-seat airplane from an existing airplane places many constraints to the new design. The GA-CAD[®] and the AutoCAD[®] softwares however were very helpful in the designing process. Results show that the RGS P4-180 has competitive performance and stability characteristics to others in its class. However, further works on the airplane cabin and wing structure are required.

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