DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DESIGN AND CONTROL OF A PNEUMATIC TRANSPORT SYSTEM

by
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September, 2009
İZMİR

DESIGN AND CONTROL OF A PNEUMATIC TRANSPORT SYSTEM

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We have read the thesis entitled **"DESIGN AND CONTROL OF A PNEUMATIC TRANSPORT SYSTEM"** completed by **ALİCAN ERÇEVİK** under supervision of **PROF. DR. EROL UYAR** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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DESIGN AND CONTROL OF A PNEUMATIC TRANSPORT SYSTEM

ABSTRACT

In this thesis, hovercrafts, the most common pneumatic transport systems and their controls are investigated. To success in hovercraft design critical points are thrust and lift systems. It can be difficult to correct errors after the craft has been completed. So the aim of this work was to develop a method of predicting the performance of a hovercraft. The relationships between lift and thrust, blade angle, engine speed, fan pressure are investigated. At the last stage, a model of hovercraft, controlled by a remote control, was designed and built according to calculations. Results are rechecked on hovercraft model.

Keywords: Hovercraft, lift and thrust system, ducted fan systems.

PNÖMATİK TAŞIMA SİSTEMİ TASARIMI VE KONTROLÜ

ÖZ

Bu tezde, en yaygın pnömatik taşıma sistemi olan hovercraftlar incelenmiştir. Hovercraft dizaynında başarılı olabilmek için kritik noktalar itme ve kaldırma sistemleridir. Taşıma sistemi yapıldıktan sonra hataları düzeltmek zor olabilir. Bu yüzden bu çalışmanın amacı hovercraft performansını öngören bir metot geliştirmektir. Kaldırma ve itme kuvveti, kanat açısı, motor hızı, fan basıncı arasındaki ilişkiler araştırılmıştır. En son aşamada ise hesaplara dayalı uzaktan kumanda ile kontrol edilebilen bir hovercraft model yapılmış ve sonuçlar tekrar model üstünde kontrol edilmiştir.

Anahtar sözcükler: Hovercraft, itme ve kaldırma sistemleri, kanallı fan sistemleri.

CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Introduction to Hovercraft

Hovercraft is a vehicle that can travel over both land and water. It was invented by Christopher Cockerell in 1956. It is also called air cushion vehicle or ACV. It rises above the surface on a cushion of air.

Figure 1.1 Hovercraft rising on land.

Figure 1.2 Hovercraft is landing.

Hovercraft can be powered by one or more engines. Thrust and lift are two important forces for hovercraft. If the craft has several engines, thrust and lift forces are supported by different engines. One of them is responsible for lifting the vehicle by forcing high pressure air under the craft. Other additional engines provide thrust in order to drive craft forward. Small crafts usually have one engine. They use ducted fan systems. Fan is diverted by a splitter plate. A portion of the air flow provides lift force and the rest of the air passing out of the back to push the craft forward. These crafts are called integrated hovercraft.

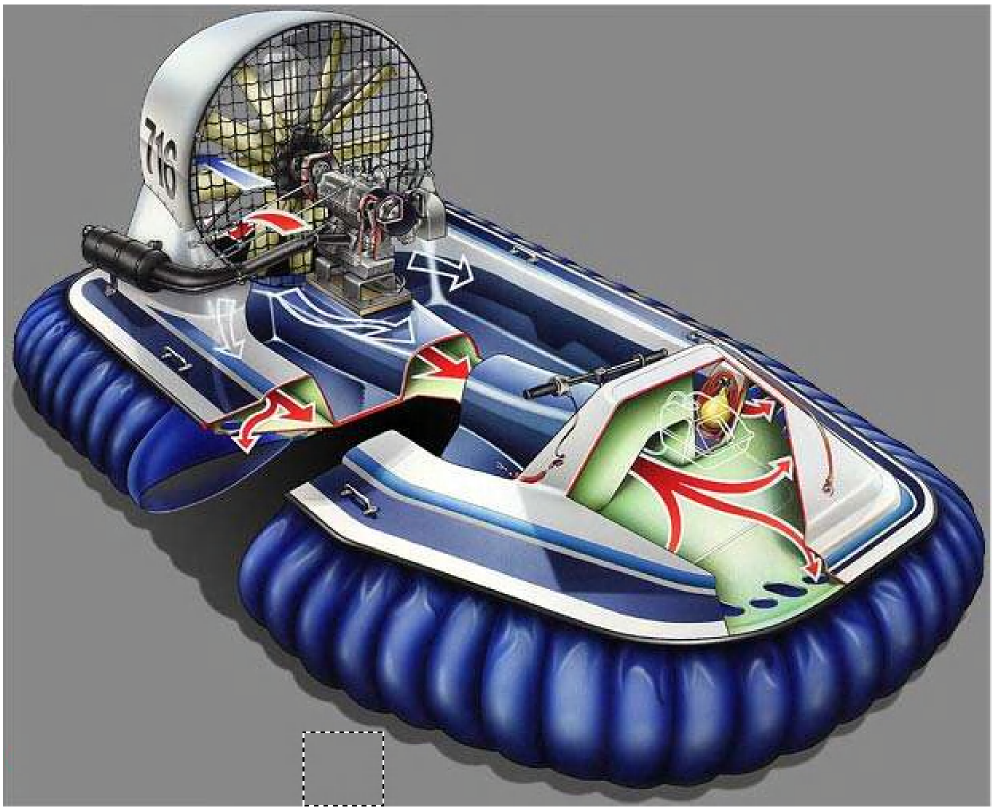

Figure 1.3 Integrated hovercraft layout.

1.2 Applications of Hovercraft

Applications of hovercraft can be written in 4 topics.

1.2.1 Civil Ferry Applications

Hovercraft can be used as passenger ferries, logistics vehicles or personal craft. Transport can be done on shallow water, beaches, swamps and other regions which conventional ships find it difficult to have access to. The first passenger-carrying hovercraft to enter service was the Vickers VA-3, which in the summer of 1962 carried passengers regularly along the north Wales Coast from Moreton, Merseyside, to Rhyl. It was powered by two turboprop aero-engines and driven by propellers.

1.2.2 Military Applications

Military Forces easily saw the benefit of hovercraft. It can travel over rocks which can easily damage a normal ship. It is a new landing vehicle for military services. It is easy way to transport tanks over swamps. As one example, the US Navy continues to develop its amphibious landing fleet with the LCAC, each of which can accommodate heavy or medium sized tanks and landing troops. Landing ships constructed in the future must possess the capability to accommodate the LCAC. The effectiveness of the US Navy craft, and Russia's equivalent, has resulted in Japan forming its own squadron for coastal defence duties (Yun & Bliault, 2000).

1.2.3 Arctic Transport

Hovercrafts can be used on ice as transport and communication vehicles. They can also be used as ice breakers.

1.2.4 Load Transporters

Hovercrafts can also be used in closed areas like factory, warehouses or workshops. They used carrying load from one machine to another in the factory.

CHAPTER TWO
WORKING PRINCIPLE OF HOVERCRAFT

Hovercraft working principle is based on air cushion theory. Development of air cushion theory is closely related to the development of hovercraft.

2.1 First Mentioned Theories for Air Cushion

Although the theories are too old, they are still useful to understand air cushion theory.

2.1.1 Thin Peripheral Jet Air Cushion Theory

The peripheral jet system was used in the early days of development of the air cushion technology. Figure 2.1 shows schematic of this system. In this system, a curtain of air is produced around the periphery by ejecting air downward and inward form nozzle. This curtain of air helps contain the cushion under the vehicle and reduces air, which runs away from the cushion area. Therefore, it could offer higher efficiency than the simple plenum chamber.

Cushion pressure produces lift force, but in addition to this, the air jet also provides a small amount of vertical lift. Under steady-state conditions, the weight of the vehicle W is balanced by the lift force F_{cm} is calculated (Wong, 2001) as

$$F_{CM} = W = p_{CM} A_c + J_j l_j \sin\theta_j \tag{2.1}$$

p_{CM} : Cushion pressure

J_j : Momentum flux of the air jet per unit length of the nozzle.

L_j : Nozzle perimeter

θ_j : Angle of the nozzle form the horizontal.

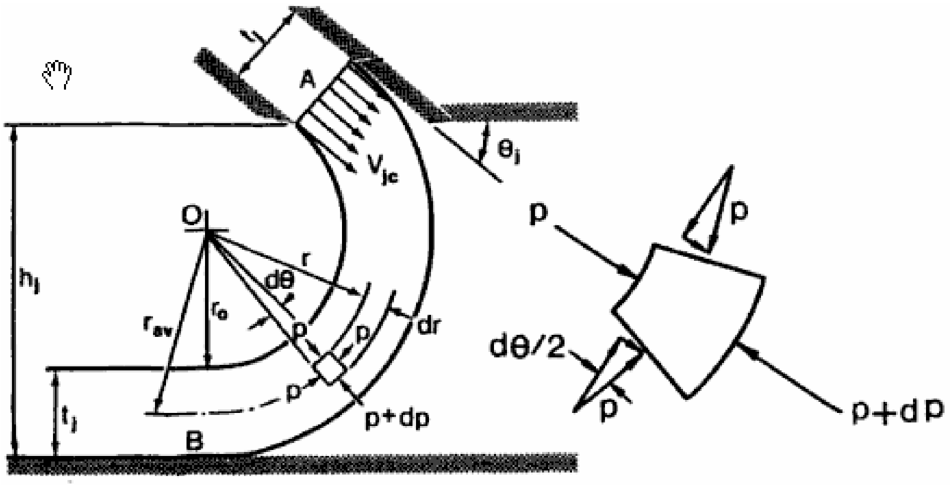

Figure 2.1 Geometry of peripheral jet system.

2.1.2 Exponential Theory for Air Cushion

Mr. Stanton-Jones of the British Hovercraft Corporation developed a relation based on the assumptions that the back pressure at the edge of nozzle, namely the side close to the atmosphere, was equal to the pressure of the atmosphere, and the back pressure at the inner edge of the nozzle was equal to p_c.

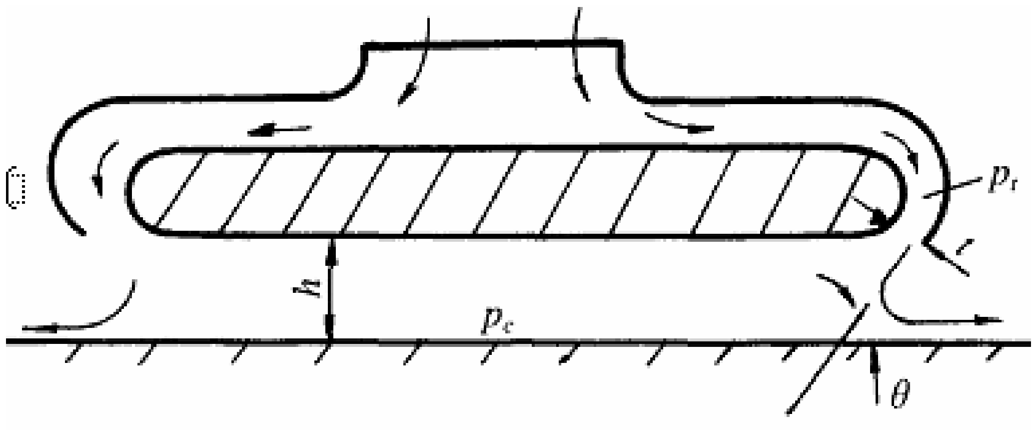

Figure 2.2 Cushion cross section.

The flow rate and total pressure of the lift fan can then be derived (Yun & Bliault, 2000) as

$$p_c / p_t = 1 - e^{-2x} \qquad (2.2)$$

$$x = (1+\cos\theta)t/h \tag{2.3}$$

$$Q = [2/\rho_a]\{l_j h p_t^{0.5}[1-(1-p_c/p_t)^{0.5}]/(1+\cos\theta)\} \tag{2.4}$$

p_c : Cushion pressure (N/m^2)

p_t : Total pressure (N/m^2)

t : Width of nozzle (m)

h : The air clearance (m)

2.1.3 Plenum Chamber Theory

This theory is similar to thin peripheral jet air cushion theory. For plenum chamber theory duct configuration is different. So the flow streamline for the air escaping from the cushion periphery is different. A typical example section for this type is shown in Fig 2.3. The cushion flow is pumped from air ducts directly into the cushion rather than from peripheral nozzles as for a peripheral jet hovercraft. Flow diffuses in the plenum chamber and forms the air cushion. For this reason, the relation may be derived simply because the pressure in the plenum chamber can be considered as a uniform distribution. In fact, this was validated by testing of manned craft, with the exception of hovercraft operating at high speed and with high frequency heaving and pitching. Thus the unit flow rate around the craft periphery can be written as follows (Yun & Bliault, 2000)

$$Q = [2p_c/\rho_a \mu.h.l_j] \tag{2.5}$$

.

2.1.4 The A.A. West Single Wall Theory

A.A West singe wall theory based one major rule.

- The total pressure along the section of jet and the static pressure along the nozzle are always constant.

(Yun & Bliault, 2000) point out the calculations as shown below.

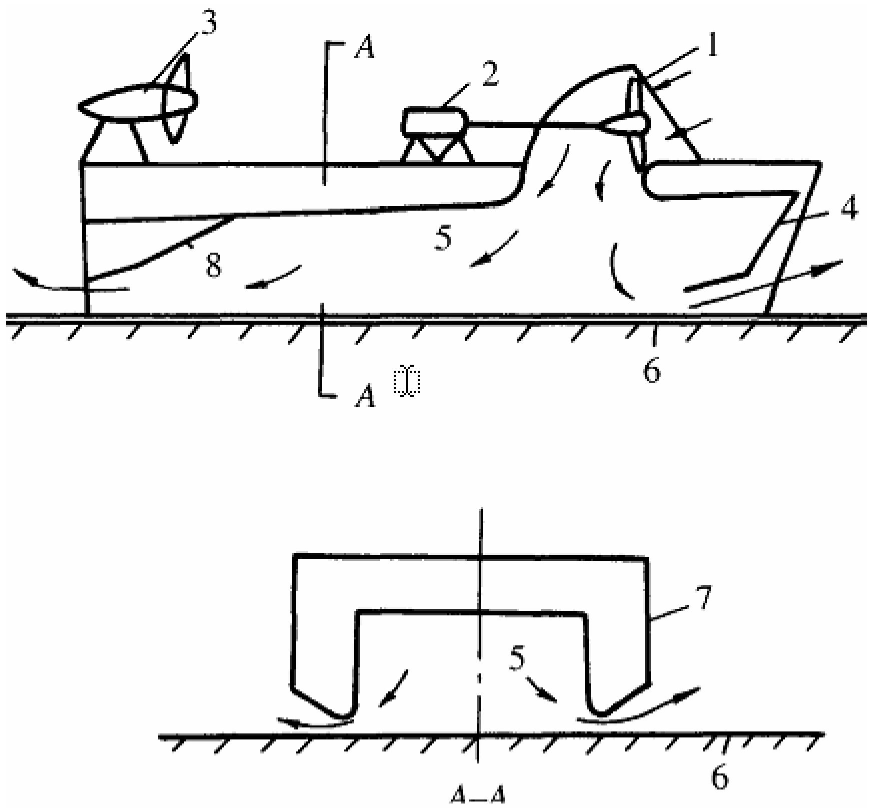

Figure 2.3 Cross section of plenum chamber cushion 1: lift fan, 2: lift engine, 3: propulsion engine and propeller, 4: bow seal, 5: air cushion plenum chamber, 6: rigid surface, 7: sidewall, 8: stern seal.

Flow momentum for the air jetted into the cushion, per unit length of nozzle, may be written as follows

$$M_j = \rho_a V_j^2 t \tag{2.6}$$

According to the Bernoulli equation, the total pressure of the jet at the nozzle, the sum of the static pressure head and dynamic (kinematic) pressure, can be written as

$$p_t = p_c + 0.5\rho_a V_j^2 \tag{2.7}$$

thus

$$M_j = 2(p_t - p_{c)}t \tag{2.8}$$

where V_j is the jet velocity at nozzle, t the nozzle thickness, p_c the cushion pressure and p_t the total pressure of the jet at the nozzle.

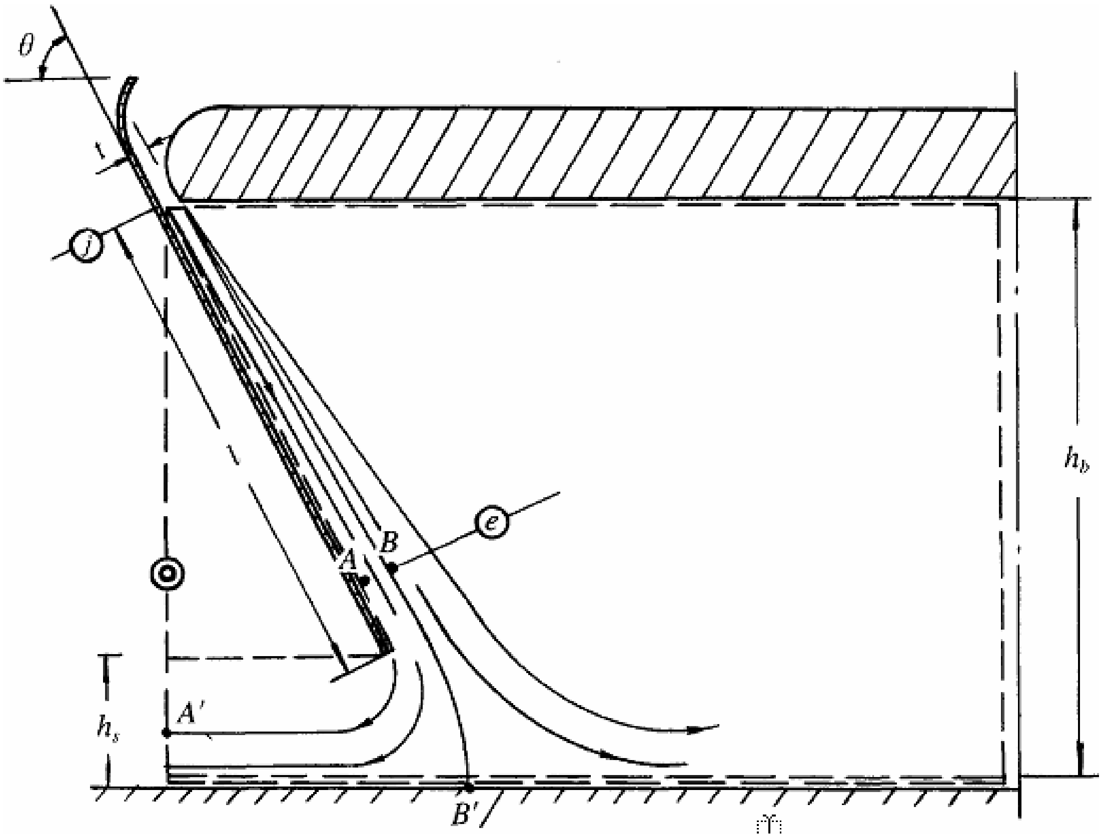

Figure 2.4 Hypothesis for air jet streamlines based on A. A. West's single wall theory.

Meanwhile, it is assumed that the flow momentum per unit length of air curtain along the streamlines AA' and BB' to the atmosphere was *M* and remains constant at the locations e and o. On this basis there is no loss of flow momentum along the streamline AA'.

According to Newton's formula, the equation which describes the controlling section shown in Fig. 2.4 may be written as follows:

$$M_j \cos\theta + M_e = p_c h_b - p_0 h_s - \int_0^1 p \sin\theta dl \tag{2.9}$$

where h_b is the vertical distance between the rigid bottom of the craft and the rigid surface, h_s the vertical distance between the lower tip of the single wall skirt and the rigid surface, p the static pressure of cushion air on the inner wall of the skirt, p_0 the atmospheric pressure, and l the length of the angled skirt wall.

The static pressure locally along the inner wall of a skirt is variable, hence the integral in the last term of equation (2.9). The closer it approaches the lower tip of the skirt, the lower the pressure and nearer to atmospheric pressure. However, globally it is reasonable to assume that the static pressure mentioned above is constant, namely cushion pressure pc and then the above formula may be written as

$$M_j(\cos\theta + M_e / M_j) = (p_c - p_0)h_s \quad (2.10)$$

Based on the Mayer velocity distribution and boundary layer thickness for a two dimensional jet with enclosing wall and turbulent flow, the ratio of flow momentum at section e to that at section j has been derived by A. A. West as follows:

$$M_{e/}M_j = 2.75(l/t)^{-0.45} = 2.75((h_b - h_s)/(t\sin\theta))^{-0.45} \quad (2.11)$$

where h_s is the air clearance of the nozzle.

Upon the substitution of equations (2.8) and (2.11) in equation (2.10), we have

$$\frac{p_c - p_0}{p_t - p_0} = \frac{1}{1 + \{h_s /[2t\cos\theta + 2.75((h_b - h_s)/t\sin\theta)^{-0.45}]\}}$$

Thus, the flow rate per unit air curtain length can be written as

$$m = \rho_a[2(p_t - p_c)/\rho_a]^{0.5} t/h_s$$

or

$$\frac{m}{[\rho_a(p_c - p_0)]^{0.5}} = \left|\frac{1}{h_s[\cos\theta + 2.75((h_b - h_s)/(t\sin\theta))^{-0.45}]}\right| \tag{2.12}$$

The lift power per unit air curtain area can be written as

$$N[\rho_a/(p_c - p_0)^3]^{0.5} = (2^{0.5}t/h_s)[1 + \{h_s/[2t\cos\theta + 2.75((h_b - h_s)/t\sin\theta)^{-0.45}]\}]^{0.5}$$
$$x\{h_s/[2t\cos\theta + 2.75((h_b - h_s)/t\sin\theta)^{-0.45}\ ]\}^{0.5} \tag{2.13}$$

CHAPTER THREE
DESIGNING AN INTEGRATED HOVERCRAFT

Craft overall size, weight, performance, control, cost, noise, life expectancy, appearance, requirements for maneuverability and comfort are the parameters which designer should firstly think about.

Performance capability, and size are more important then the others. After that, principle subsystems such as lift system, thrust system, skirt and cushion system should be determined. Analysis outlined in this chapter is designed for typical integrated hovercraft layout shown in Figure 1.3.

3.1 Lift Characteristics

3.1.1 First lift

This is the first lift point which skirt is filled with air. Craft shows signs of lifting. But there is no hover gap craft is still stationary. This means that cushion pressure is equal to the lift pressure but the airflow is assumed to be negligible.

For the calculations, it may be useful to assume a small lift air flow at this point.0.3m^3/sec air flow is enough for calculation. This is really a theoretical point.

3.1.2 Design Lift

On this point it is assumed that there is no friction between craft skirts and floor. Design lift point, expressed in engine rpm, represents the craft hovering on a smooth ice. Hover gap value is equal to design value. Because of the escaping air, craft lose from cushion pressure. So the cushion pressure is the sum of lift pressure and air flow pressure.

For good maneuverability, this point should be on same line with minimum thrust.

3.1.3 Maximum Lift

Maximum lift point, expressed in engine rpm, represents the craft hovering on a shingle or long course grass. In the calculations air flow is multiplied with coefficient for this point.

This point represents the limit of the craft performance. For good maneuverability, at this point thrust should be maximum too. So craft can manoeuvre away from difficult location.

3.2 Thrust Characteristic

Thrust is the force that moves a hovercraft forward. It comes from either a propeller or a commercially available fan.

3.2.1 Minimum Static Thrust

Minimum thrust and design lift point have an important relationship. Because it represents the minimum thrust that can be applied whilst hovering.

3.2.2 Maximum Static Thrust

This is the maximum thrust associated with a given design.

3.3 Formulas for Integrated Hovercraft

As mentioned above, we need to write equations for the various parts of the lift system.

$Pressure_{fan}$=f (flow rate, rpm)

$Pressure_{transfer\ holes}$=f (flow rate)

Cushion pressure =f (craft mass)

3.3.1 Lift Calculation

For calculating lift force, the first think we need to know total weight of the craft including passengers. Second one is the area of the craft, enclosed by the skirt points.

3.3.1.1 Cushion Pressure

$$p_c = \frac{m_c g}{a_c} \quad (3.1)$$

p_c : Cushion pressure (Pa)

m_c : Craft mass, ready to fly, including payload, fuel etc. (kg)

a_c : Cushion area which is enclosed by skirt points (m^2)

3.3.1.2 Discharge Coefficient

Discharge coefficient depends on the angle formed between the skirt and the ground

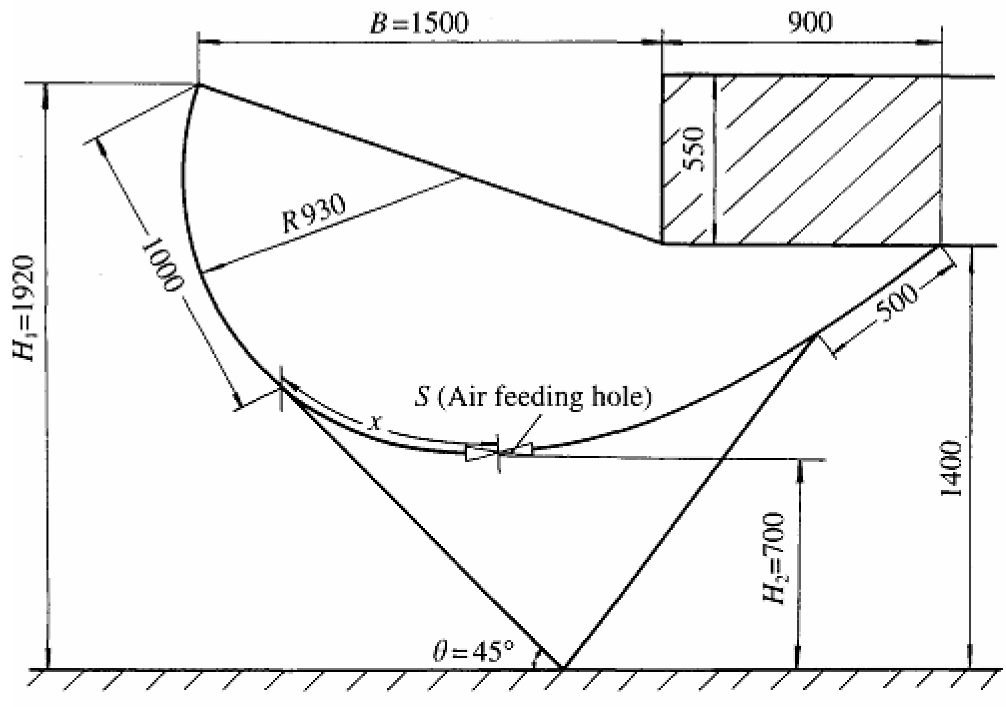

Figure 3.1 Cross section of a skirt which has 45 degree θ from ground.

(Brooks, 2005) defines discharge coefficient for the escape of cushion air using the Von Mises formula.

$$D_c(\theta) = 0.5 + \frac{0.4.10^{-3}}{\deg}\theta + \frac{0.109.10^{-4}}{\deg^2}\theta^2 - \frac{0.494.10^{-7}}{\deg^3}\theta^3 + \frac{0.345.10^{-9}}{\deg^4}\theta^4 \quad (3.2)$$

$D_C(\theta)$ can be calculated for different skirt angles.

3.3.1.3 Cushion Flow Rate

(Brooks, 2005) calculate the flow rate of air escaping from the cushion as

$$v_{nom} = \sqrt{\frac{2}{\rho} p_c} h.CP_c.D_c(\theta) \quad (3.3)$$

υ_{nom} : Volume of air escaping from cushion area (m^3/sec)

ρ : Air density (kg/m^3)

p_c : Cushion pressure (Pa)

CP_c : Perimeter of craft at the skirt points

$D_C(\theta)$: Discharge coefficient

3.3.1.4 Pressure loss from transfer holes

Air sucked in to the duct by the help of propeller. A portion of air, which is called lift air, guide inside to transfer duct by splitter plate. This air pass through the transfer holes and goes into the plenum chamber, enclosed by skirt. See Figure 3.2. During this process, air lose some pressure called transfer hole pressure loss.

Pressure drop due to these holes is significant and should be taken into account. (Brooks, 2005) defines transfer hole pressure loss as

$$\Delta p_t(v) = \frac{\rho}{2}\left(\frac{v}{a_t D_C(\theta_t)}\right)^2 \tag{3.4}$$

a_t : Total Area of plenum transfer holes

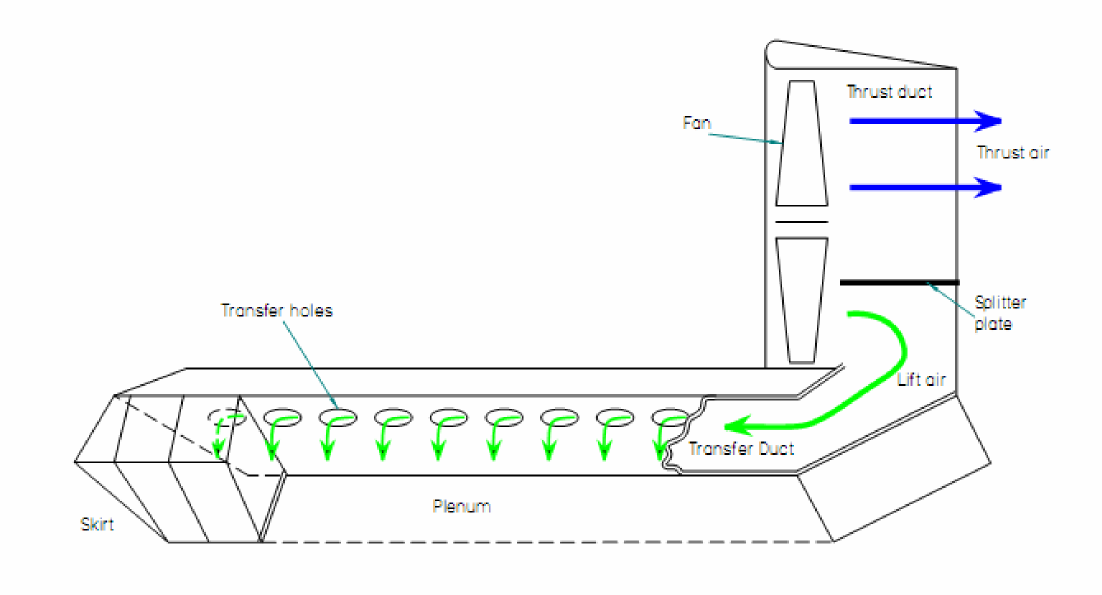

Figure 3.2 Air streamline in a integrated hovercraft.

3.3.1.5 Determination of Lift Characteristic Points

There is three important characteristic lift point that must be calculated before design.

- First lift point
- Design lift point
- Maximum lift point

Important of these characteristic lift points is explained in 3.1.

Table 3.1 Characteristic point properties

Lift Point	Cushion Pressure	Cushion flow rate	Fan pressure
	Pa	m^3/sec	Pa
First Lift	p_c	Zero	p_c
Design Hoer	p_c	Q_d	$p_c+\Delta p_{t1}$
Max Hover	p_c	$Q_d.k_s$	$p_c+\Delta p_{t2}$

3.3.1.5.1 Determination of First Lift Point. This is the first lift point which skirt is filled with air. Cushion pressure and flow rate can be calculated form equation 3.1 and 3.3.

3.3.1.5.2 Determination of Design Lift Point. At that point loss of pressure from transfer holes must be included.

$v_1 = v_{nom}$

Fan pressure = $\Delta p_{t1}(v_1) + p_c$

$$\text{Fan pressure} = \frac{\rho}{2}\left(\frac{v_1}{a_t D_C(\theta_t)}\right)^2 + \frac{m_c g}{a_c} \qquad (3.5)$$

3.3.1.5.3 Determination of Maximum Lift Point. At this point coefficient k_s must be taken in to account. (Brooks, 2005) gives the coefficient k_s as shown below.

Table 3.2 Design factor for non ideal surface conditions

Non ideal surface conditions		Design Factor coefficient k_s
ice	=	1
hard mud	=	1.2
very short or wet grass	=	1.3
sand or 4" grass (pliable)	=	1.4
short course grass	=	1.5
wet or sticky mud or long pliable grass	=	1.6
very choppy water or long course grass	=	1.7
very sticky mud or shallow shale	=	>1.8

Cushion design flow rate must be calculated as shown below.

$v_2 = v_{nom} k_s$

Fan pressure = $\Delta p_{t1}(v_1) + p_c$

$$\text{Fan pressure} = \frac{\rho}{2}\left(\frac{v_2}{a_t D_C(\theta_t)}\right)^2 + \frac{m_c g}{a_c}$$

(3.6)

3.3.2 Determination of Thrust

(Fitzpatrick, 2003) describe thrust as a force applied by the volume of air passed at the discharge of the fan. The basic equation for thrust is given below.

$$T = Q_d V_d \rho \qquad (3.7)$$

T : Thrust without drag or losses (N).
Q_d : Quantity of air at discharge velocity (m^3/sec).
V_d : Discharge velocity (m/sec).
ρ : Density of air (kg/m^3).

But this formula must be modified including the drag momentum. In which condition does the drag momentum comes out? Fans take the air inside the duct and increase its velocity and pressure. If the air has also thrust against the fan, it can't increase the pressure same amount. This means,

$$T_{net} = T - T_{drag}$$

$$T_{drag} = Q_d V_0 \rho$$

$$T_{net} = (Q_d V_d \rho) - (Q_d V_0 \rho)$$

$$T_{net} = Q_d \rho (V_d - V_0)$$

Q_d can be written as A x V_d then,

$$T_{net} = V_d A \rho (V_d - V_0) \qquad (3.8)$$

A : Fan area (m^2).

3.3.3 Choosing Fan and Engine

After calculating maximum lift pressure from equation 3.6, we can decide which fan we will use.

It is important that to decide the hovercraft type. If it has two engines, this means thrust fan and lift fan will be different. This is the most important point for choosing fans.

Every fan has different characteristics. Also same fun has different characteristic under different conditions. Characters shown below for a fan are enough to make decision.

- Static pressure
- Air flow
- Rpm
- Power consumption
- Noise
- Efficiency
- Blade angle
- Tip speed
- Discharge velocity

Assuming that maximum lift pressure is 500Pa and enough flow rates for cushion are is 2.1m^3/sec. Figure 3.3 and Figure 3.4 are the characteristic curve for different two fans. Both of them have three blade and same diameter. Red dot on the curves is point out the working point. Table 3.3 shows the differences between two fans.

Table 3.3 Values taken from figure 3.3 and figure 3.4

	D:600mm, 3 Blade, 3500rpm, 25deg Blade Angle	**D:600mm, 3 Blade, 2900rpm, 35deg Blade Angle**
Rpm	3500rpm	2900rpm
Air flow	2.2 m^3/sec	2.2 m^3/sec
Static pressure	500Pa	500Pa
Power consumption	2.59HP	3.18HP
Efficiency	%58.3	%50.4

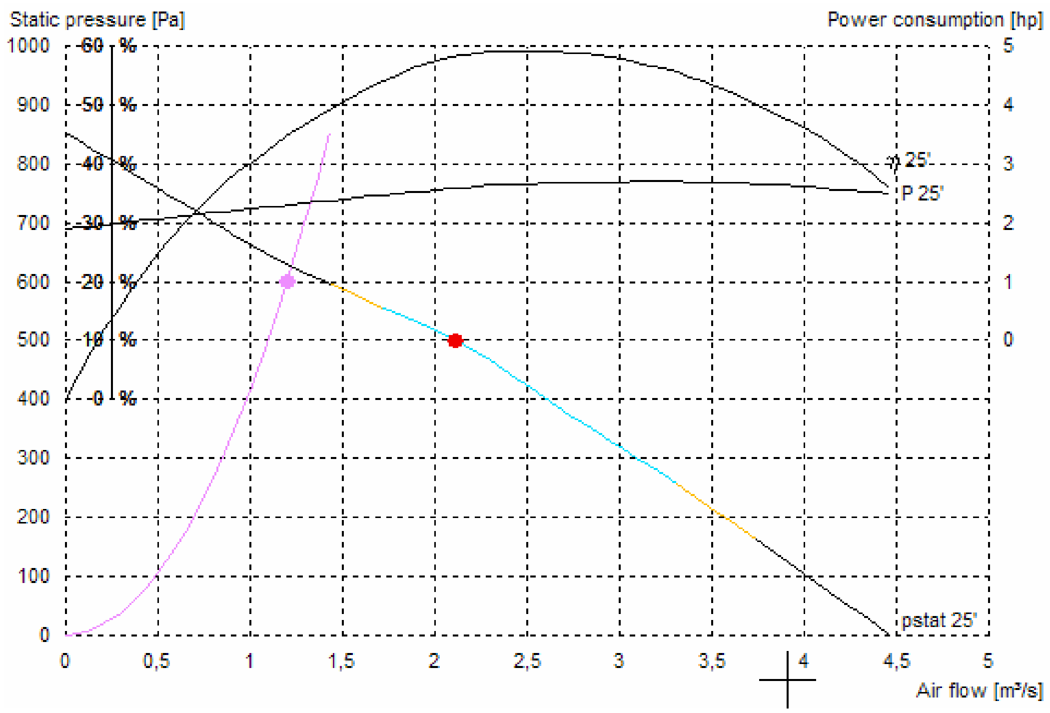

Figure 3.3 Wingfan D=600mm, 3 Blade, 3500rpm, 25deg Blade Angle.

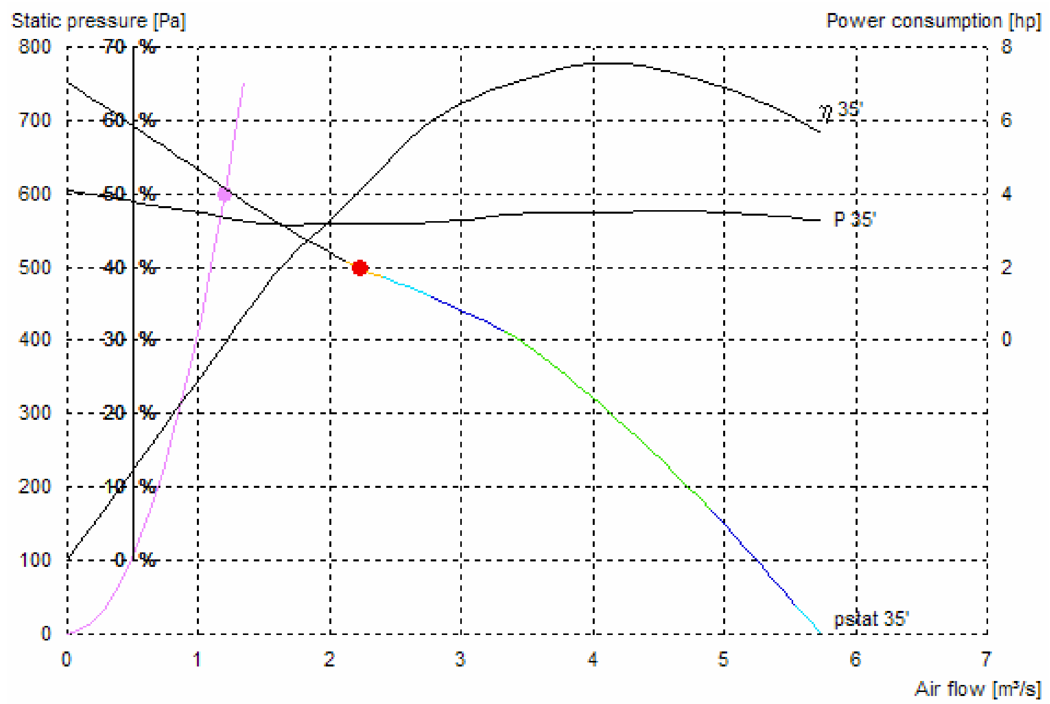

Figure 3.4 Wingfan D=600mm, 3 Blade, 2900rpm, 35deg Blade Angle.

Both fans are suitable for working point. But the one which has 25degree blade can reach to working point later then 35 degree. On the other hand 25 degree blade is more efficient and consumes less power on same rpm. So the choice is depend on what is wanted and also to the engine.

Engine power curve and fan power curves play an important role of selecting fans and engines. It is not possible to find power curves for every fan. But it is possible to calculate depending on one sample by the help of fan laws. (Brumbaugh, 2004, chap. 7) gives a detailed chapter about fan laws.

1. Fan speed delivery will vary directly as the cfm ratio.

$$NewRPM = OldRPM \times \left[\frac{NewCFM}{OldCFM} \right]$$

2. Fan and system pressures will vary directly as the square of the rpm ratio:

$$NewSP = \left[\frac{NewRPM}{OldRPM} \right]^2 \times OldSP$$

3. Brake horsepower (bhp) on the fan motor (or air horsepower of the fan) will vary directly as the cube of the rpm ratio:

$$NewBHP = \left[\frac{NewRPM}{OldRPM} \right]^3 \times OldBHP$$

By the help of 3^{rd} law and matlab program, power curves for these two fans easily plotted. See the Figure 3.5.

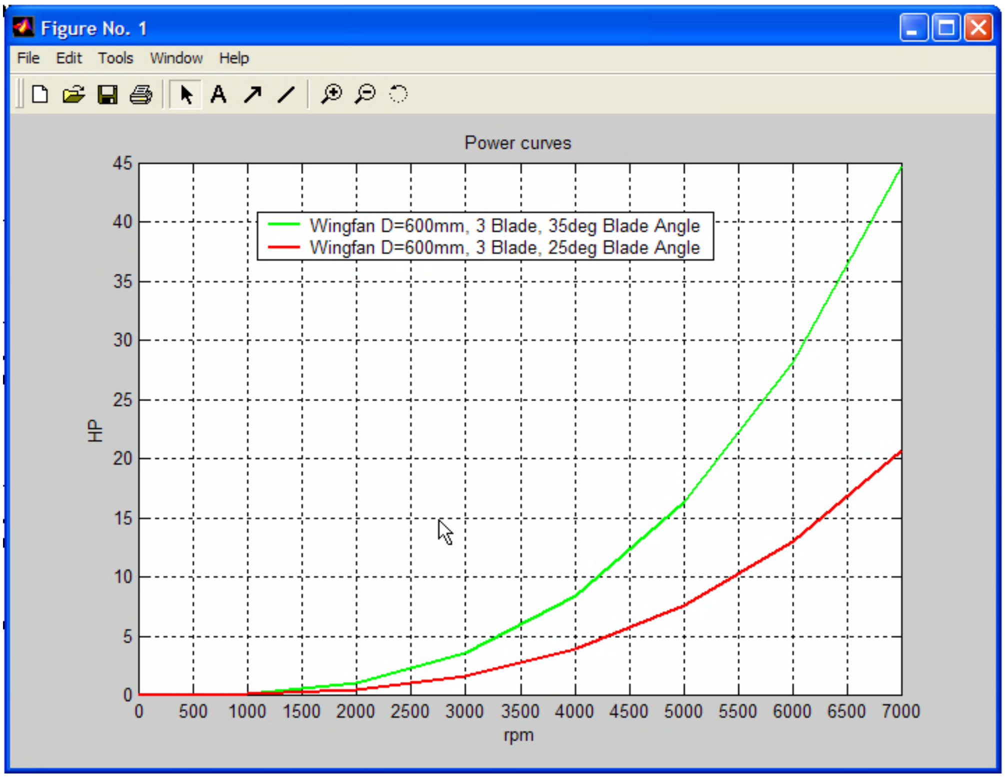

Figure 3.5 Power curves for Wingfan D=600mm, 3 Blade, 2900rpm, 35deg Blade Angle and D=600mm, 3 Blade, 3500rpm, 25deg Blade Angle.

(Fitzpatrick, 2003) gives an example in his work. Engine curve belongs to Kawasaki KR1 motorcycle and fan curve belongs to 900mm 6-12/5Z Multi-Wing fan.

From figure 3.6 can be seen that around 10000rpm engine can supply approximately 60BHP and fan consume all of it. There is no power available to accelerate the fan to higher speeds. This means that fan curves above the engine curve are not suitable for this engine.

3.4 Designing a Skirt

A skirt should cover the following requirements.

- It should supply the enough cushion air at the design hover height.
- After having deformed it must return to its original shape.
- It should give the adequate stability.

- It should have long operating life.

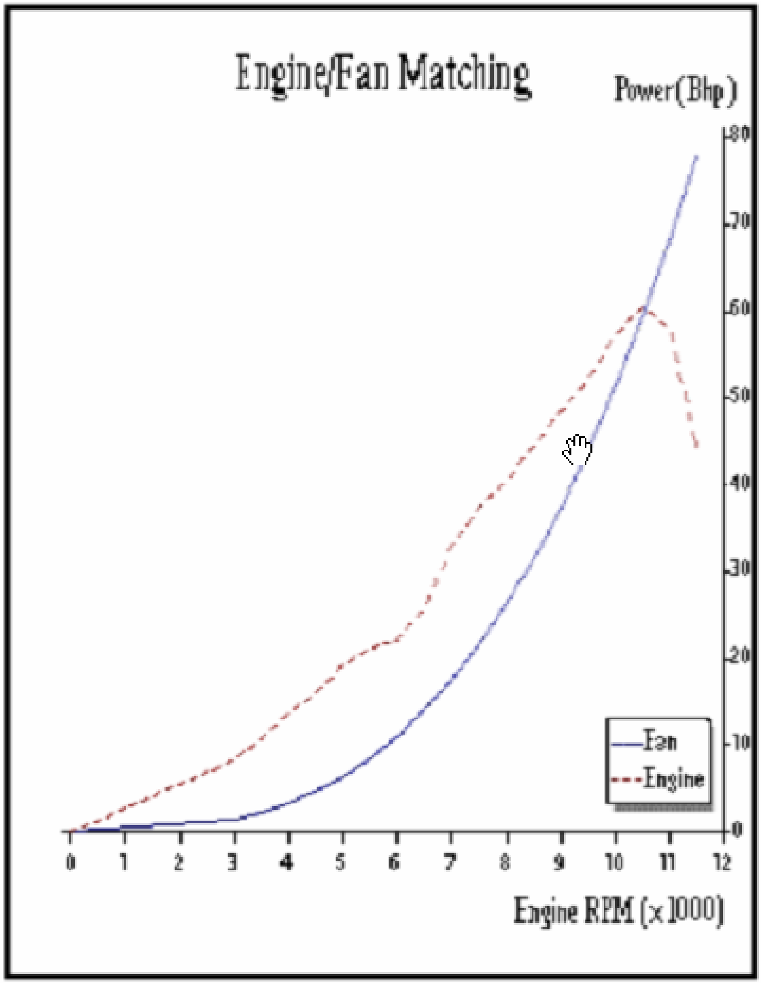

Figure 3.6 Kawasaki KR1 motorcycle engine curve and 900mm 6-12/5Z Multi-Wing fan curve matching.

There are several types of hovercraft skirts, but the most commons are jupe skirt, bag skirt, finger skirt and bag finger skirt.

3.4.1 Jupe Skirt or Cell Skirt

This skirt type is the simplest one. It is also known as cell skirt. Jupe skirts are difficult to inflate especially while sitting on a surface like grass.
Each cell is separate from others as seen in Figure 3.7.This means each jupe should be fed directly from the fan to obtain maximum cushion stability. It is used on Sedam N.300, Sedam N.500, Be11 Carabao, Aerojet Manta.

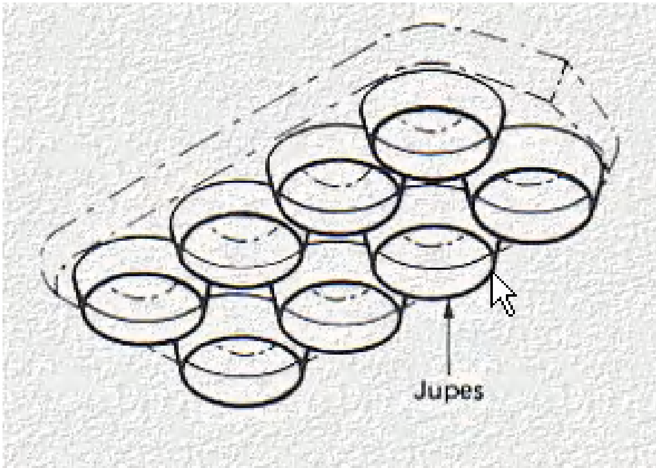

Figure 3.7 Jupe skirt or cell skirt type.

3.4.2 Bag Skirt

Bag skirt is simple to design and construct. But it gives a more drag force then finger type skirt. Depending on the pressure it has limited clearance while facing with obstacle. Lift system feeds all the air into the skirt. After that air pass through small holes in the inner skirt wall into cushion. It is possible to change pressure by controlling the number and the size of the holes.

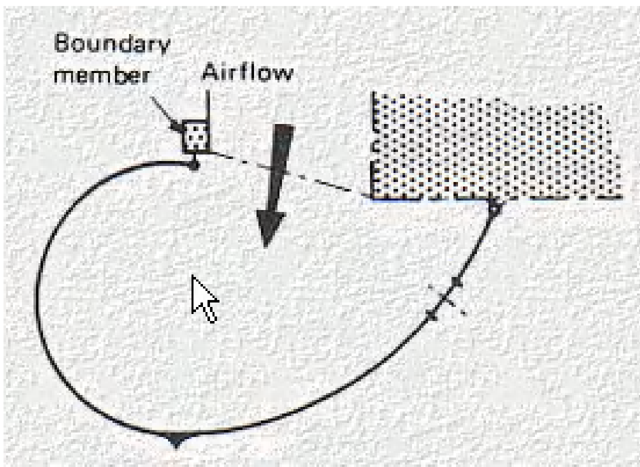

Figure 3.8 Bag skirt type.

3.4.3 Finger skirt

Finger skirt has less resistance when passing over grass or rough ground. It is easy to design and construct. It is consist of small size segments. So repair work is also easy. It also has good sealing properties. This means less dust, less noise and less horsepower. At lift off, a hovercraft with a finger skirt does not take water into like a bag skirt. However, they are not as stable as the bag or jupe skirts.

Figure 3.9 A hovercraft with finger skirt.

3.4.4 Bag and Finger Skirt

Bag and finger skirt system is most widely used one. But it has still problems. (Chung, 1997) point out its problem as its tendency to produce a rough ride and other is its susceptibility to an instability known as skirt bounce.

Bag behaves like a damper. It provides comfort while driving on the waves at high speed. By the help of fingers, drag forces are reduced. It is easy to repair fingers. They are made by small pieces. Even with the partial loss of up to 3 fingers, craft can go further. And also for repairing, it is easier and cheap to replace 3 fingers than a whole bag.

3.4.5 Comparisons between Skirt Types

(Fitzgerald & Wilson, 1995) point out advantages and disadvantages between skirt types in table 3.4.

Table 3.4 Comparisons between skirt types.

	Bag	Segmented/Finger	Jupe/Cell
Cost	Low	High	Low
Labor	Low	High	Medium
Drag			
Smooth water	Same	Same	Same
Rough water	High	Low	Very high
Mud	High	Low	Low
Grass	High	Low	Medium high
Ice	Same	Same	Same
Smooth snow	Medium	Low	Low
Rough snow	High	Low	Medium
Repairability	Hard	Easy	Hard
Life	Good	Moderate	Good
Durability	Good	Poor	Moderate
Stability	Good	Poor	Excellent
Plow in	Same	Same	Same
Roll ability for turning	Slight	Excellent	Light
Dust and spray	Poor	Good	Poor
Colors available	Limited	Unlimited	Limited
Ease of attachment	Moderate	Easy	Moderate hard
Weight of skirt	Low	Moderate	Low
Hump performance	Moderate	Good	Poor moderate
High speed	Good	Moderate	Moderate
Bulkiness	Poor	Poor	Good
Appearance	Moderate	Good	Moderate
Bounce	Poor	Good	Good
Performance when damage	Moderate	Good	Poor
Potential for development	Good	Good	Good
Over water rapid take off ability from long time floating mode	Poor	Good	Excellent
Obstabcle capability	Poor	Good	Poor
Complexity	Low	High	Moderate

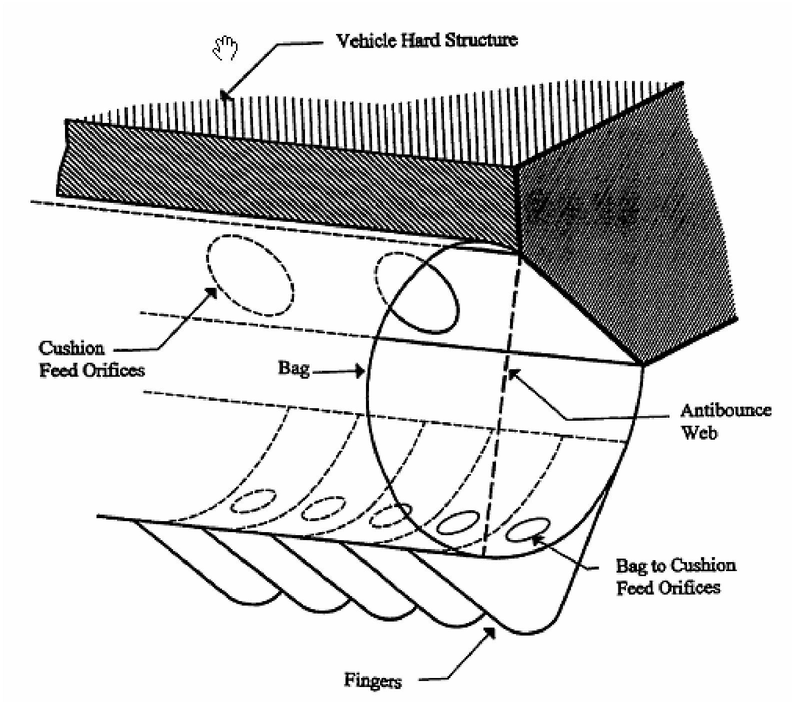

Figure 3.10 Cross section of a bag and finger skirt.

CHAPTER FOUR

IMPLEMENTATION

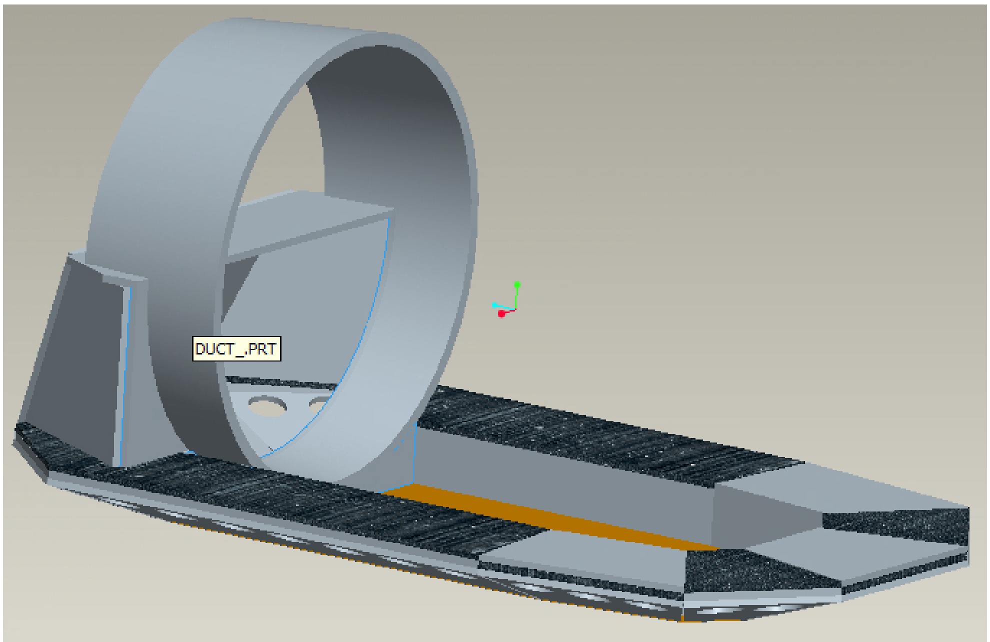

Figure 4.1 Model hovercrafts design photo from CAD program.

4.1 Craft Overall Size

Deciding outer dimensions for hovercraft is important. Length (L) and width (W) determine the lift surface for craft. If we look through hovercrafts dimensions from past to today, they are longer then they are wide. (Fitzgerald & Wilson, 1995) describe L/W as shown below.

$L/W \leq 2$	For standard craft
$L/W \leq 3$	For high speed craft

If the hovercraft hovers too high, it results with instability. Because of this, crafts hover close to the ground. According to (Fitzgerald & Wilson, 1995), a maximum overall height (D) to width (W) ratio for small hovercraft is 1:1 but more usually 1:2. D is measured from the tip of the propeller to the ground while craft is hovering.

In the light of above information, I decided model hovercraft outer dimensions. See figure 4.2.

Length (L) = 750mm
Width (W) = 450mm
Maximum overall height (D) = 385mm

$$L/W = \frac{750}{450} = 1.7 \leq 2$$

$$D/W = \frac{385}{450} = 0.85$$

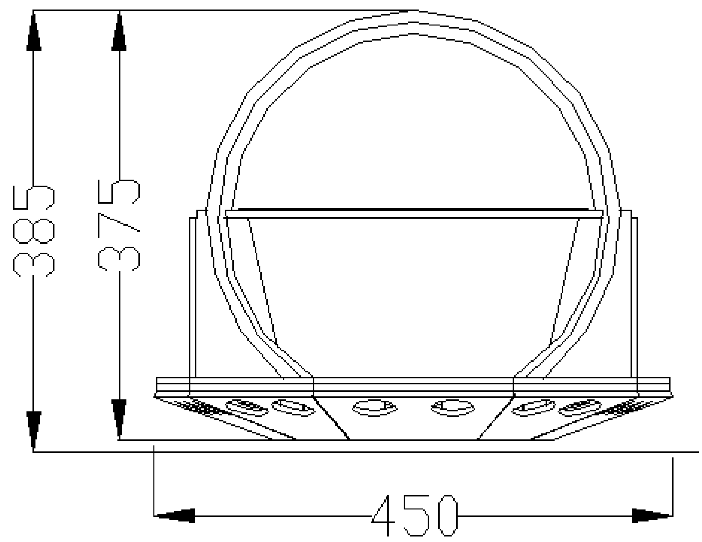

Figure 4.2 Front view of model hovercraft.

Perimeter of craft is needed for calculation of flow rate of air escaping from the cushion. It is calculated as 2.1m.See Figure 4.3

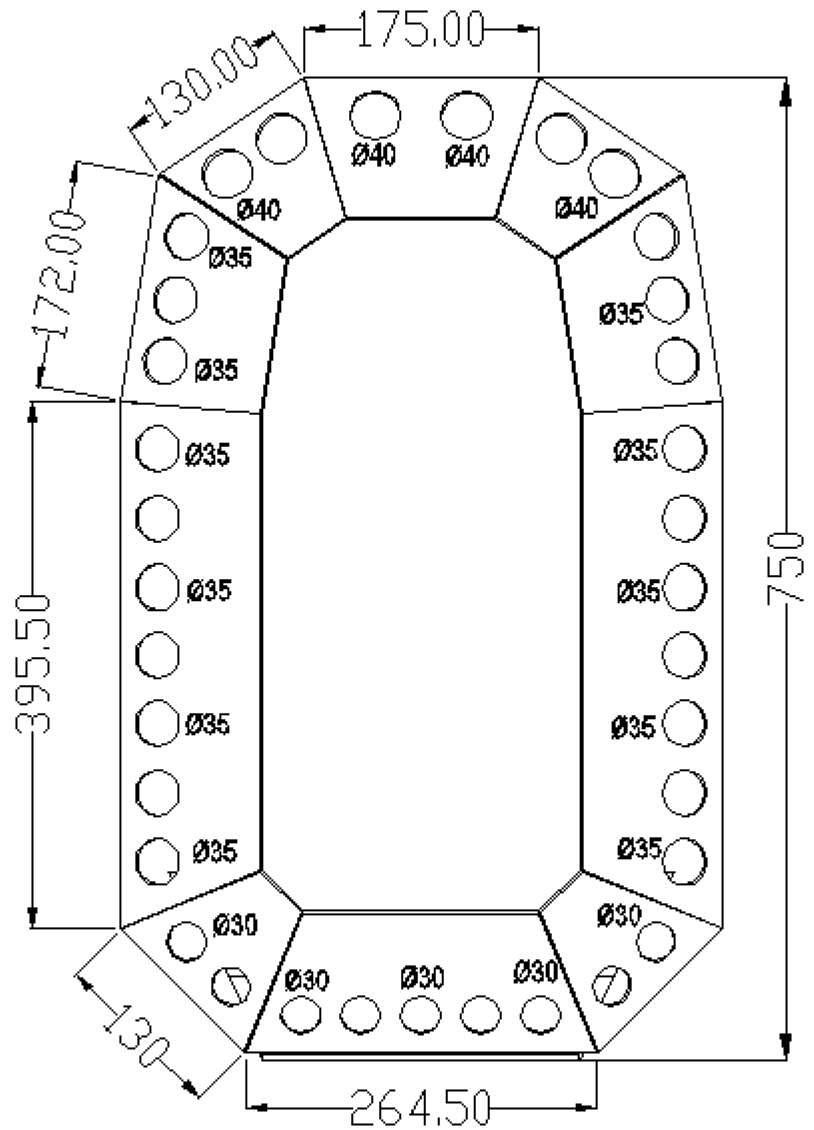

Figure 4.3 Model hovercraft perimeter and transfer holes diameter.

4.2 Craft Weight

The model is made by medium density fiberboard (MDF). MDF is resin impregnated, pressed wood fiber product that can be shaped, sawed and drilled with common woodworking tools. Strength and mechanical properties of MDF is shown in Table 4.1 (Hoadly, 2000).

Table 4.1 Strength and mechanical properties of MDF

Property	**Unit**	**Value for medium density fiberboard**
Density	pcf	33 - 50
Specific gravity	-	0.53 – 0.80
Modulus of elasticity (bending)	1.000psi	325 - 700
Modulus of rupture	psi	1900 - 6000
Tensile strength parallel to surface	psi	1000 - 4000
Tensile strength perpendicular to surface	psi	40 - 200
Compressive strength parallel to surface	psi	1000 - 3500
Shear strength (in plane of board)	psi	100 - 475
Shear strength (across plane of board)	psi	600- 2500
24-hour water absorption	% by volume	-
24-hour water absorption	% by weight	5 – 20
Thickness swelling 24-hour soaking	%	2 – 10
Linear expansion from 50% to 90% relative humidity	&	0.2 – 0.4
Thermal conductivity at mean temperature of 75F	Btu per inch thickness per hour per square foot of surface per degree Fahrenheit	0.54 – 0.75

MDF has a density of 600 – 800 kg/m^3. Calculated volume from CAD program for model hovercraft is 7.09x10^{-3} m^3. Craft weight is approximately 5 kg. Including 0.5kg motor weight, 0.5kg fuel weight and max 3kg payload it is totally 9kg.

4.3 Calculating Lift Points

Cushion area (A_c) calculated as 0.3m^2. From equation 3.1, cushion pressure is figure out as 294.3 Pa. This is first lift point pressure. Discharge coefficient is calculated for 45° skirt angle θ_s as 0.537. According 10mm desired hover clearance and 0.537 discharge coefficient; flow rate of nominal air escaping from the cushion is calculated from equation 3.3 as 0.24m^3/sec.

This hovercraft is designed for driving over hard mud. Design factor k_s is taken in to account from table 3.2 as 1.2.

$$\nu = \nu_{nom} k_s \tag{4.1}$$

ν is calculated as 0.29m^3/sec

Model craft has 35 transfer holes in three different size. They are getting bigger in front of the craft as seen from figure 4.3.

d_{t1}=30mm	Diameter of plenum transfer holes, size 1
d_{t2}=35mm	Diameter of plenum transfer holes, size 2
d_{t3}=40mm	Diameter of plenum transfer holes, size 3

n_{t1}= 9	Number of size 1 plenum transfer holes
n_{t2}= 20	Number of size 2 plenum transfer holes
n_{t3}= 9	Number of size 3 plenum transfer holes

$$a_t = \frac{\pi}{4}\left(n_{t1}d_{t1}^{\ 2} + n_{t2}d_{t2}^{\ 2} + n_{t3}d_{t3}^{\ 2}\right) \tag{4.2}$$

a_t is calculated as 0.033m^2 from equation 4.1. But in this case θ_s is taken into account as 90° therefore discharge coefficient is recalculated as 0.611. Pressure drop from transfer holes is calculated from equation 3.4 as 126.2 Pa.

Design lift point is calculated from equation 3.5 as 380.7 Pa. and maximum lift point is calculated from equation 3.6 as 420.5 Pa.

4.4 Choosing Fan and Engine

In model design, I have chosen Magnum XL 61A ABC engine. It is single cylinder, two cycle engine. Specifications for engine are given in table 4.2 and 4.3.

Table 4.2 Specification of Magnum XL 61 A ABC engine

	MAGNUM XL61 A ABC
Displacement	9.95cc
Bore	24mm
Stroke	22mm
Practical RPM	2000-18000
Weight	675g
Crankshaft thread size	5/16 – 24
Power	1.7KW/2.31PS

Table 4.3 Power curve data for Magnum XL 61 A ABC

RPM	HP
4000	0.4
5500	0.6
7000	1
8500	1.48
10000	1.8
11500	2.05
13000	2.19
14500	2.32
16000	2.19
18000	1.75

According to values on the table, function of power curve can solve by using the Curve Expert program. Power curve function equation for Magnum XL 61A engine is calculated from table 4.3 as shown below.

$$\text{Engine HP (rpm)} = 2.3145077.e^{\frac{-(rpm-13977)^2}{57.87618782.10^6}} \quad (4.3)$$

By using MatLAB program power function curve related to rpm is plotted. See figure 4.4.

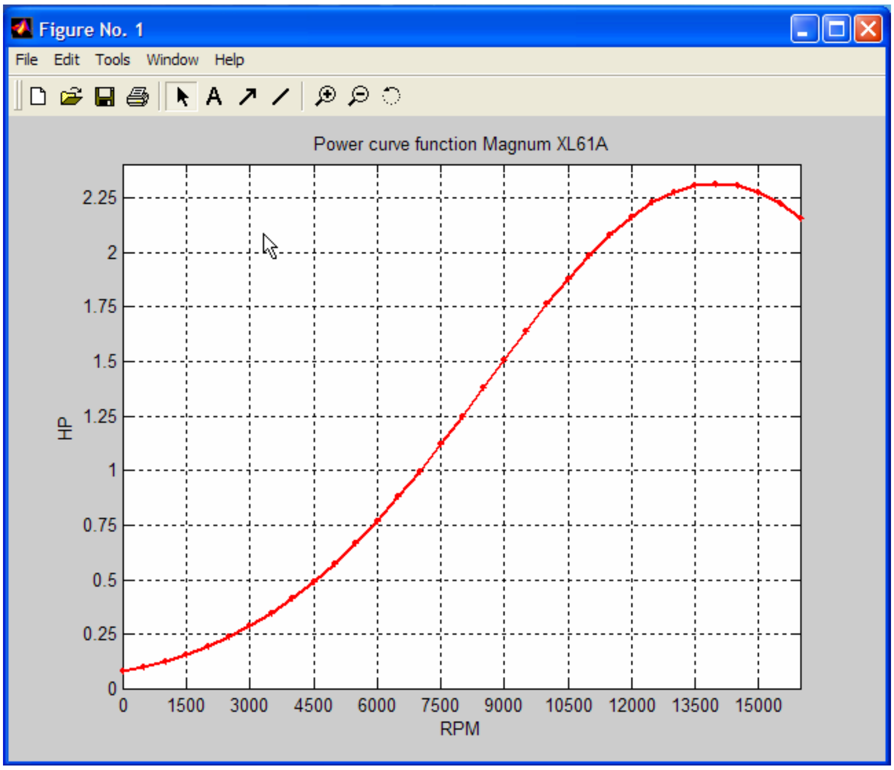

Figure 4.4 Power function curve for Magnum XL 61 A ABC engine.

Using WingFan Select 5.2 program, I have chosen Wing Fan 220/4-8/P2HL/25/PA for model hovercraft. Figure 4.5 shows the maximum lift point of the craft, which calculated above.

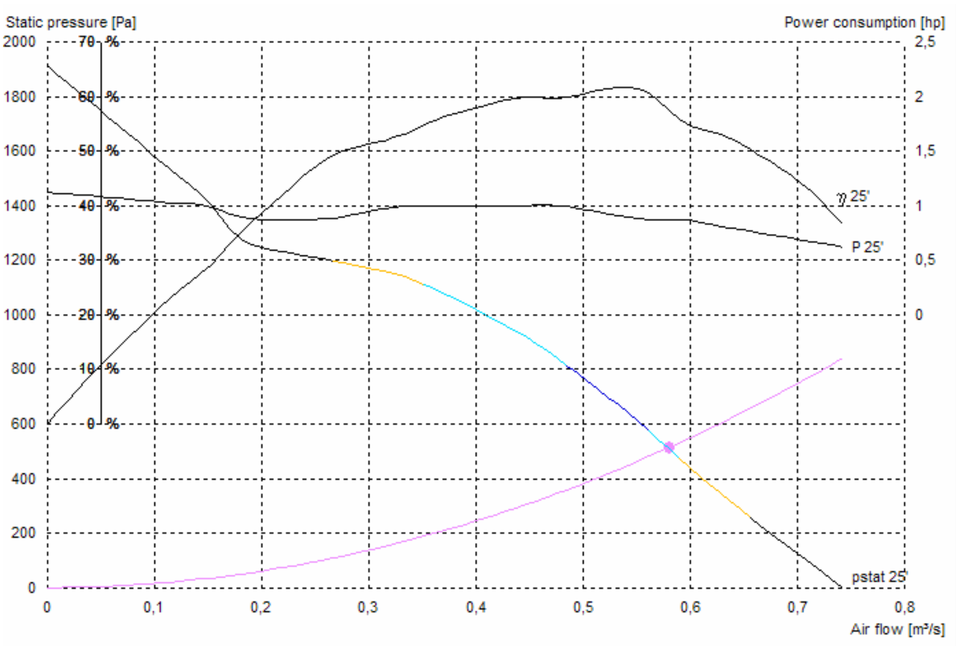

Figure 4.5 WingFan 220/4-8/P2HL/25/PA at 8000rpm.

To select suitable fan to engine, power, which is necessary for fan is calculated for each rpm by the help of table 4.4. It shows values, taken from WingFan, at 8000 rpm for various blade angles.

(Brooks, 2005) tells that, it has been determined that a 5th order polynomial curve fit provides an adequate representation of the data. Equation 4.4 describe flow rate of 220/4-8/P2HL/25/PA WingFan.

$$Q(P_S) = 0.7376 - 0.0001655P_s - 1.163.10^{-6}P_S^2 + 2.6952.10^{-9}.P_S^3 - 2.3247.10^{-12}P_S^4 + 6.2864.10^{-16}.P_s^5 \quad (4.4)$$

Table 4.4 Values for various blade angles

220/4-8/P2HL/PA								
8000rpm, 25degree			8000rpm, 30degree			8000rpm, 35degree		
Static Pressure (Pa)	Flow rate Q (m^3/sec)	Power (HP)	Static Pressure (Pa)	Flow rate Q (m^3/sec)	Power (HP)	Static Pressure (Pa)	Flow rate Q (m^3/sec)	Power (HP)
0	0.74	0.62	0	0.86	1	0	0.94	1.25
100	0.71	0.68	100	0.82	1.06	100	0.93	1.3
200	0.67	0.73	200	0.77	1.11	200	0.89	1.35
300	0.64	0.79	300	0.74	1.13	300	0.86	1.4
400	0.61	0.84	400	0.71	1.13	400	0.83	1.46
500	0.58	0.88	500	0.68	1.16	500	0.8	1.51
600	0.55	0.88	600	0.66	1.22	600	0.76	1.5
700	0.52	0.93	700	0.62	1.25	700	0.73	1.5
800	0.49	0.98	800	0.59	1.25	800	0.68	1.5
900	0.45	1	900	0.54	1.25	900	0.63	1.5
1000	0.41	1	1000	0.48	1.25	1000	0.58	1.5
1100	0.36	1	1100	0.44	1.25	1100	0.52	1.5
1200	0.26	0.89	1200	0.37	1.25	1200	0.44	1.5
1300	0.17	0.91	1300	0.23	1.28	1300	0.25	1.6
1910	0	1.25	2052	0	1.62	2105	0	2.38

Once this equation is known, it is possible to calculate flow rate for different conditions, by the help of fan laws.

According to 3rd fan low, brake horsepower (bhp) on the fan motor (or air horsepower of the fan) will vary directly as the cube of the rpm ratio.

$$NewBHP = \left[\frac{NewRPM}{OldRPM}\right]^3 \times OldBHP \quad (4.4)$$

Table 4.5 Reachable max rpm for various blade angles

Blade Angle	Max rpm
25	10700
30	8000
35	7000
40	5370

Values on table 4.5 are calculated according to 3rd fan law and also figure 4.6 shows the graphic for max rpm for various blade angles.

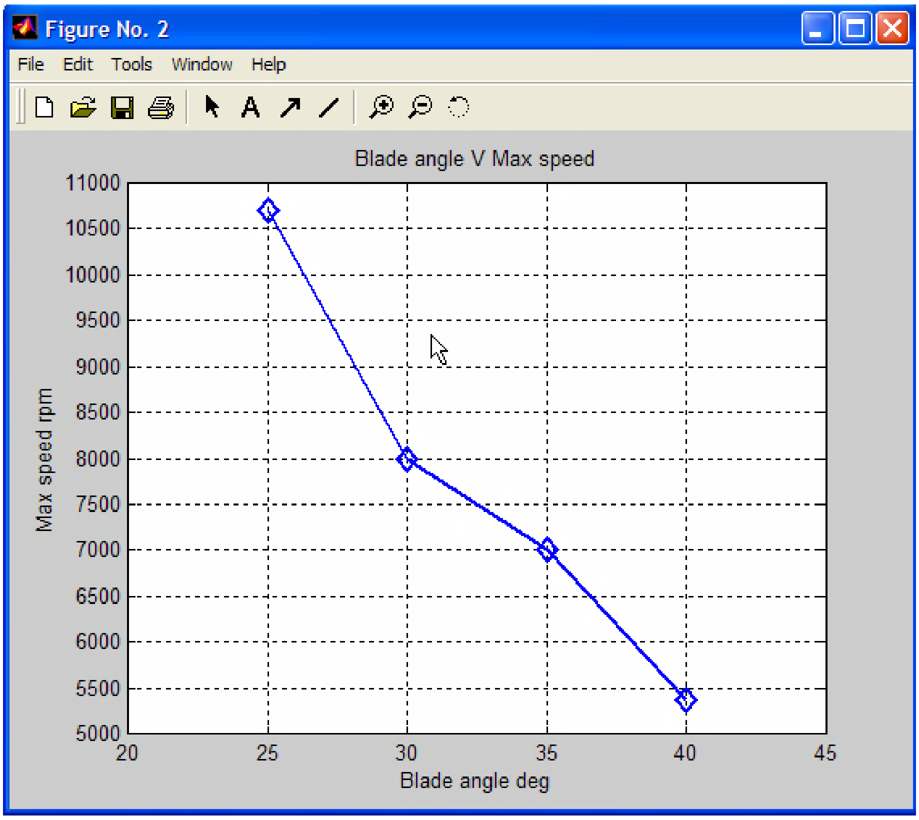

Figure 4.6 Max rpm for various blade angles.

By using MatLAB program both engine power curve and fan power curves are plotted on same chart. Figure 4.7 shows the advantages and disadvantages of different blade angels. 220/4-8/P2HL/25/PA is the suitable one that reaches max rpm and keeps its efficiency.

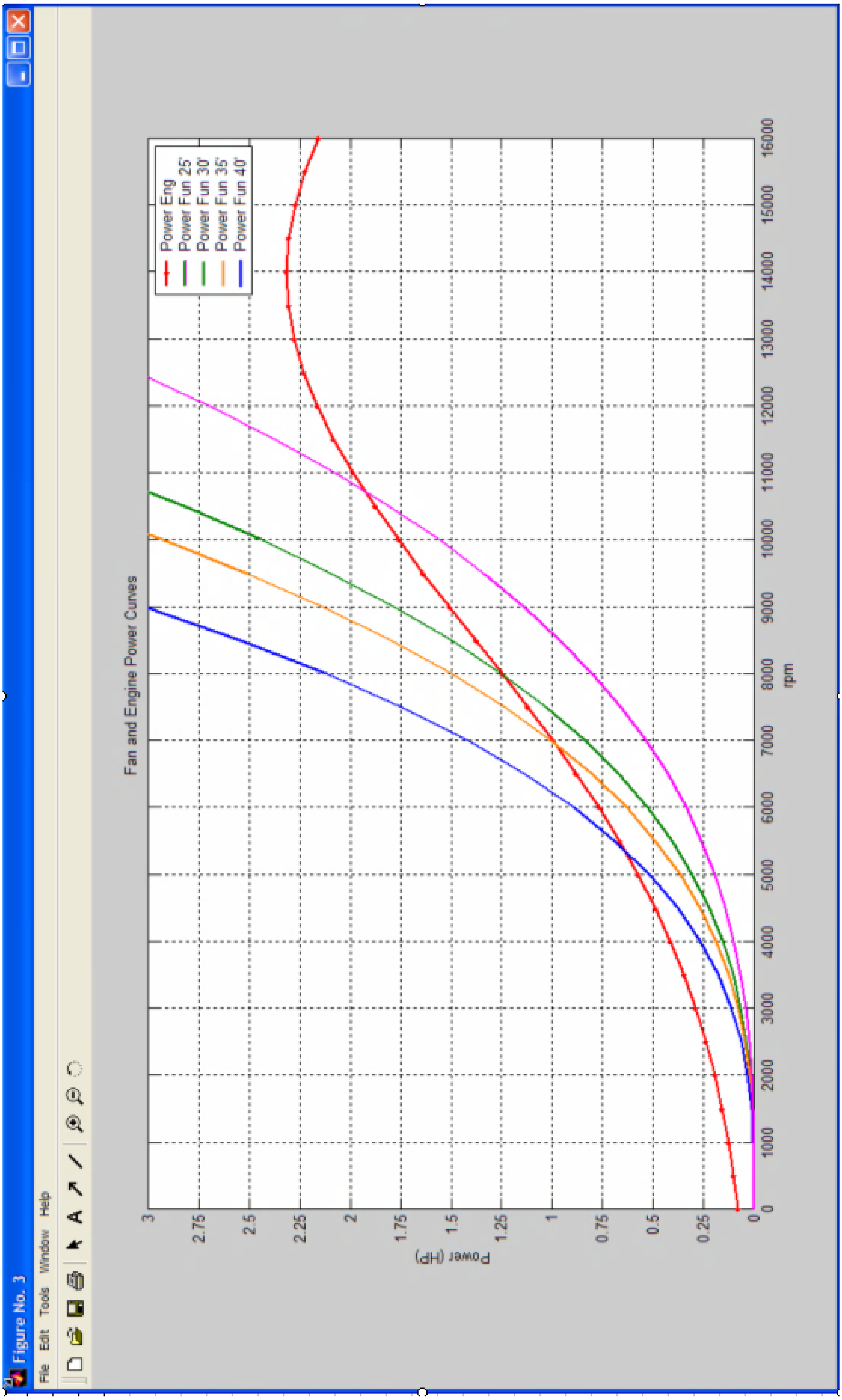

Figure 4.7 Fan and engine power curves.

As calculated above, model hovercraft needs 294.3 Pa static pressure at firs lift point, 380.7 Pa static pressure and flow rate of 0.24m^3/sec at design lift point, 420.5Pa and flow rate of 0.29m^3/sec at maximum lift point.

But calculated flow rates are only for lift. In the design thrust ratio is selected as 50%. This point will be explained later. So flow rates must multiply with two. Table 4.6 explains design points for craft.

Table 4.6 Required static pressures and flow rates for lift points

Lift Points	Cushion pressure (Pa)	Lift Air Flow Rate (m^3/sec)	Fan Static Pressure (Pa)
First lift point	294.3	0.04	294.3
Design Lift Point	294.3	0.48	380.7
Maximum lift point	294.3	0.58	420.5

Finally, for choosing right blade angle lift points is plotted on same chart with power curves. See figure 4.8 and Table 4.7

Table 4.7 Characteristic points for various blade angles

	Blade Angle 25	Blade Angle 30	Blade Angle 35	Blade Angle 40
First lift point	3500rpm 0.09Hp	3300rpm 0.1Hp	3100rpm 0.12Hp	3100rpm 0.15Hp
Design Lift Point	6900rpm 0.56Hp	6300rpm 0.61Hp	5700rpm 0.64Hp	4900rpm 0.49Hp
Maximum lift point	8000rpm 0.84Hp	7100rpm 0.83Hp	6500rpm 0.8Hp	5900rpm 0.85Hp

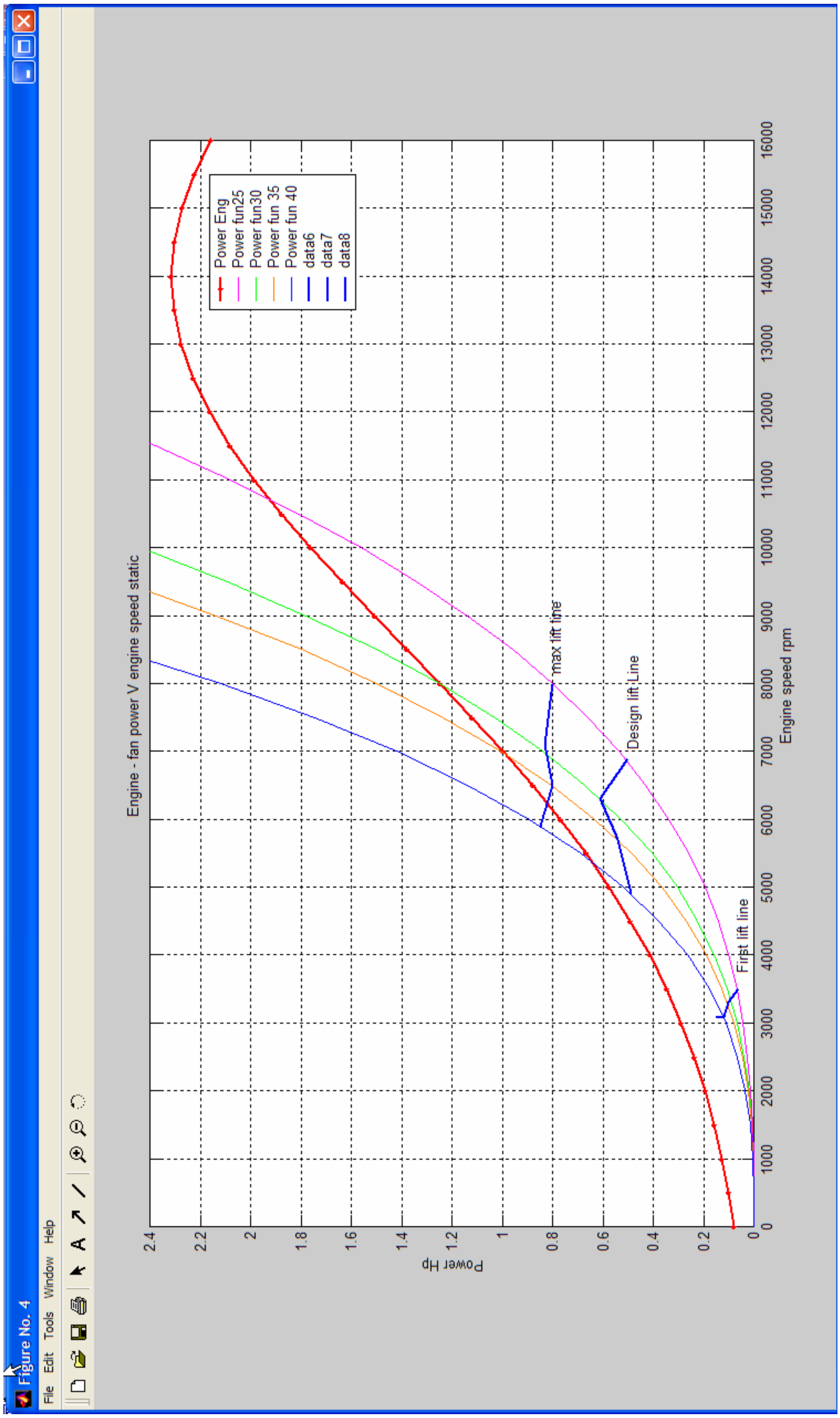

Figure 4.8 Characteristic point on power curves.

4.5 Thrust Calculation

Flow rate of air escaping from the cushion is calculated as 0.29m^3/sec.But this air is needed only for lift pressure. The model, which I built, has integrated lift system; the discharge from the fan is divided.

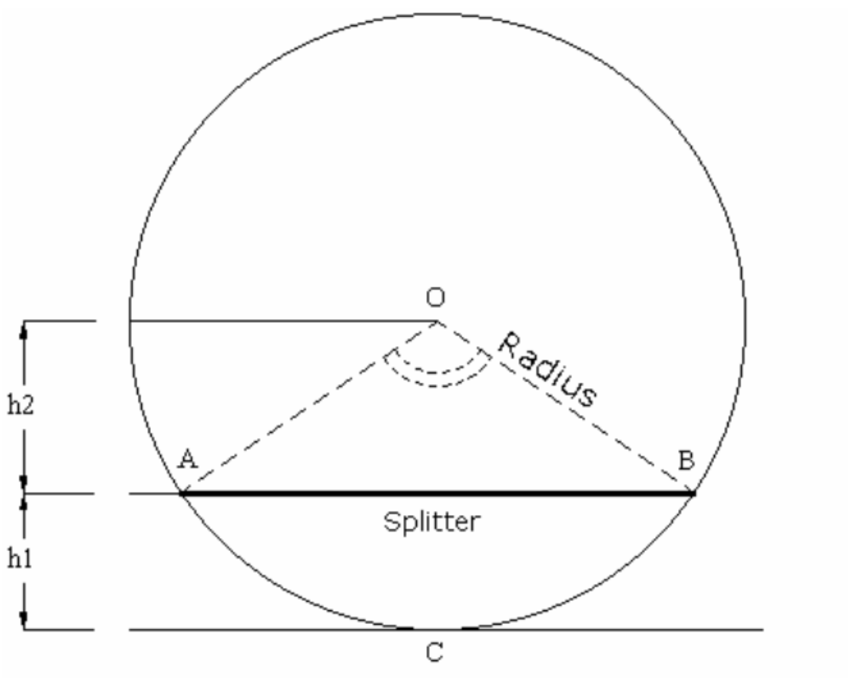

Figure 4.9 Splitter plate ratio.

Calculating splitter ratio is easy from geometry equations.

Area under splitter plate,

$$a_{sp} = R^2 \tan^{-1}\left[\sqrt{\left(\frac{R}{h_2}\right)^2 - 1}\right] - h_2\sqrt{R^2 - h_2^{\ 2}} \tag{4.5}$$

Area of duct,

$$a_d = \frac{\pi\left(d_{fan}^{\ 2} - d_{hub}^{\ 2}\right)}{4} \tag{4.6}$$

Thrust area,

$$a_{th} = a_d - a_{sp} \tag{4.7}$$

Thrust ratio,

$$k_{th} = \frac{a_{th}}{a_d} \tag{4.8}$$

It is important that increasing or decreasing the area under the splitter plate does not alter the cushion pressure; it will only alter the volume of air fed to the cushion.

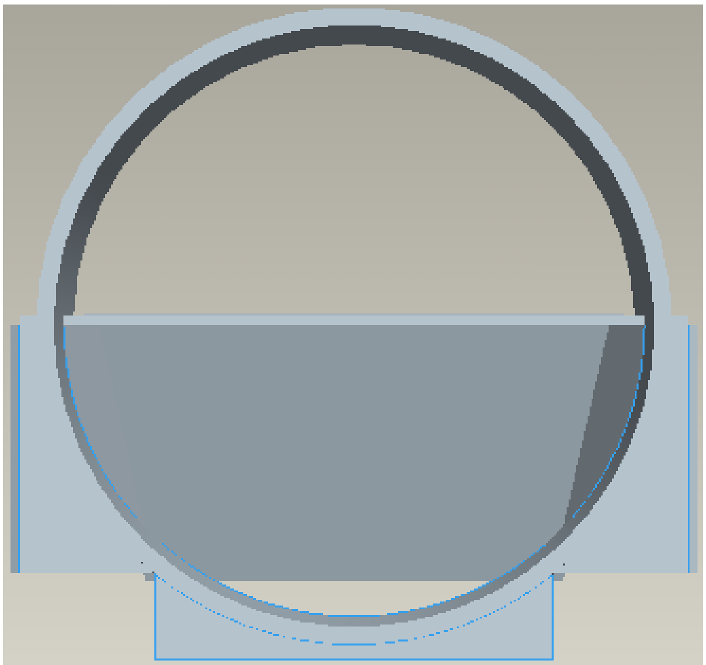

Figure 4.10 Front view of model hovercrafts duct.

In the design h_2 is equal to zero. Therefore lift ratio is 50%. At the maximum lift point engine turns at 8000 rpm. At this rpm, maximum lift point discharge velocity of the fan is equal to 15.3 m/sec. Assuming that free stream velocity is zero, from equation 3.8 thrust is calculated as 10.85 Newton.

To calculate maximum velocity, drag forces must be determined. By using equation 3.8, thrust graphic can plotted with MatLab. Aerodynamic and skirt drag forces are estimated values. Figure 4.11 shows maximum velocity approximately as 5m/sec (18km/h).

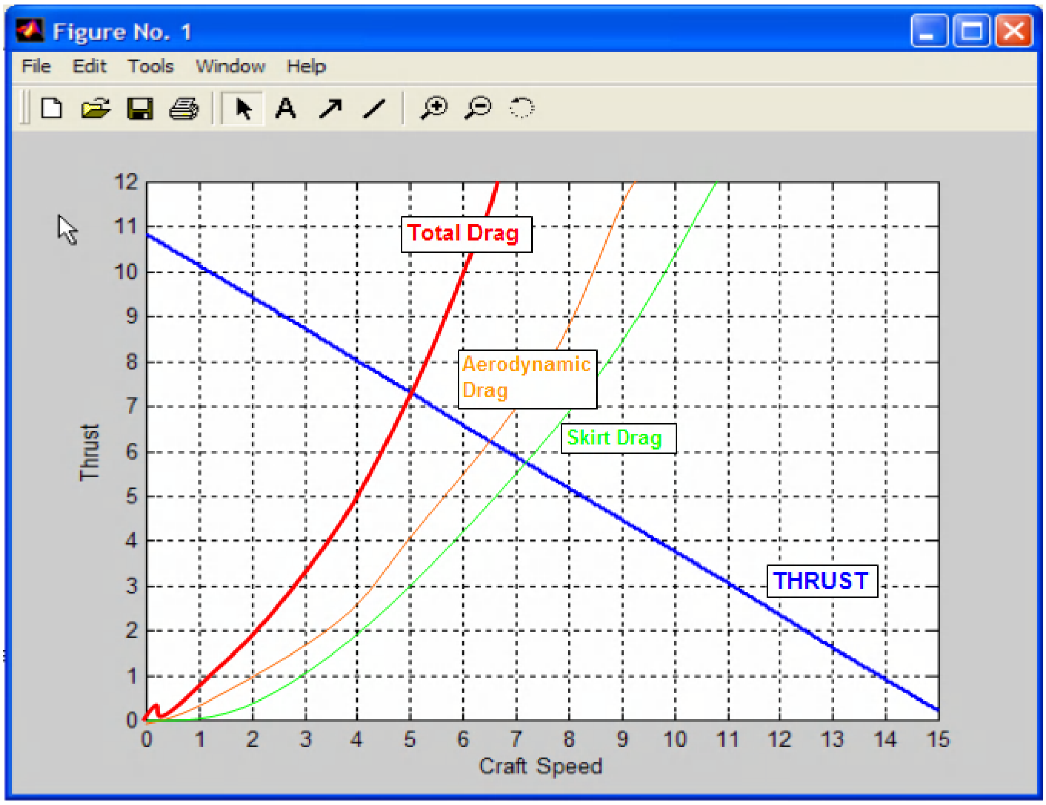

Figure 4.11 Drag forces and thrust loss.

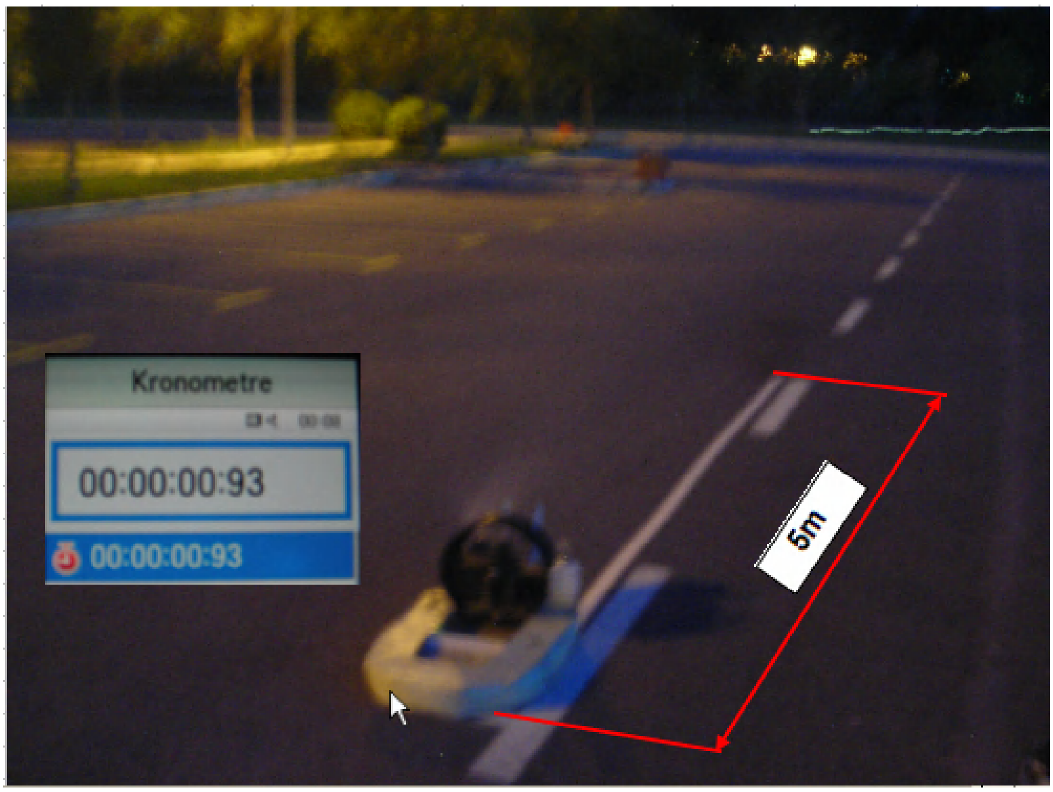

Figure 4.12 Velocity test.

According to test result model craft pass 5 meter long line in 1 sec. Figure 4.12 shows the test result.

Hovercraft weight without payload is 5.5 kg. See figure 4.13. Design weight with 3kg payload is 9kg but test results shows that hovercraft can lift and go with 6.1 kg payload with velocity of 5 km/h.

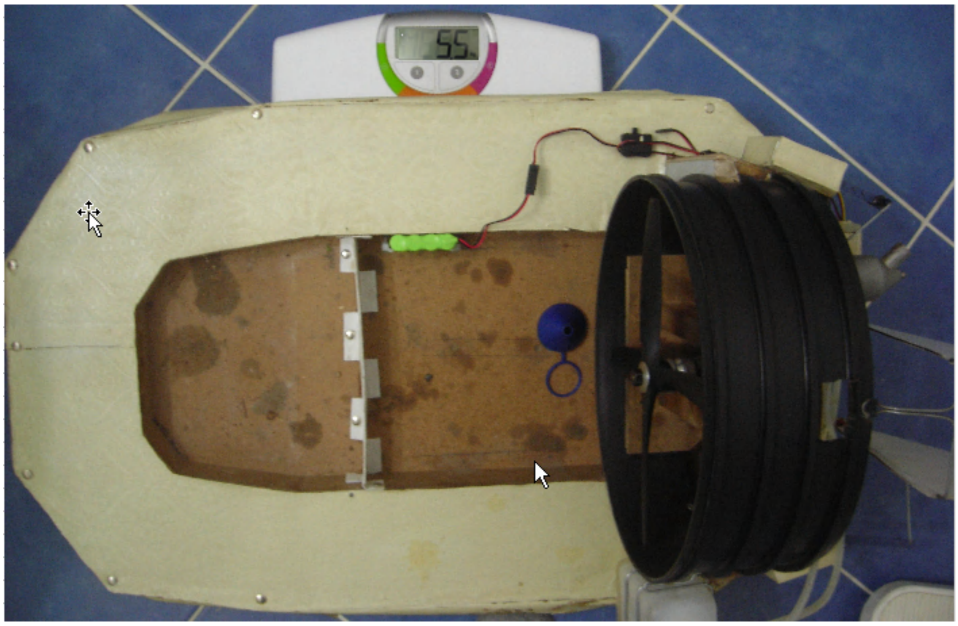

Figure 4.13 Hovercraft weight without payload.

4.6 Control

Model craft is controlled with remote control system. Two Hitech HS-322HD servos are used. One is for controlling the throttle arm, other is for controlling wings. Specifications for HS-322HD servo is given in table 4.8.

Table 4.8 Specifications of Hitech HS-322HD servo

Motor Type	3 Pole
Bearing Type	Nylon
Speed	0.19/0.15 sec@60deg.
Torque	3.0/3.7kg.cm
Size	40.00x20.00x36.50
Weight	43g

As a receiver Hitech HFS-06MT and as a transmitter Laser 4&6 is used.

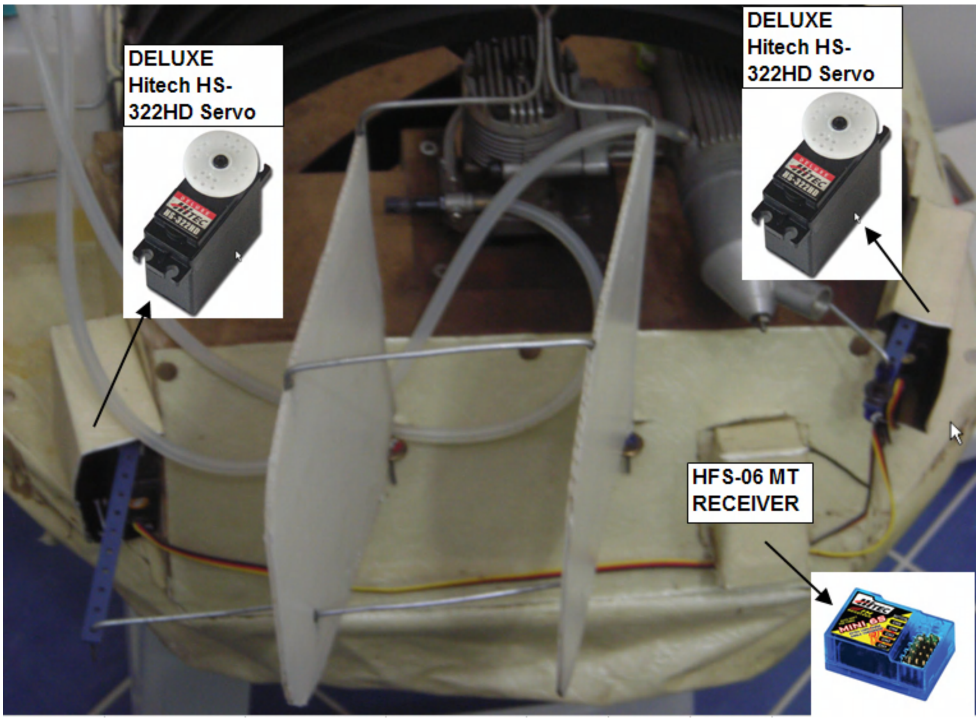

Figure 4.14 Model craft controlling unit.

Model hovercraft collimation is designed for 30 degree. HS-322HD servo is adjusted to totally 60 degree. Half of it is used for turning right and half of it for left. Figure 4.15 and 4.16 is design photo from CAD program for the wings.

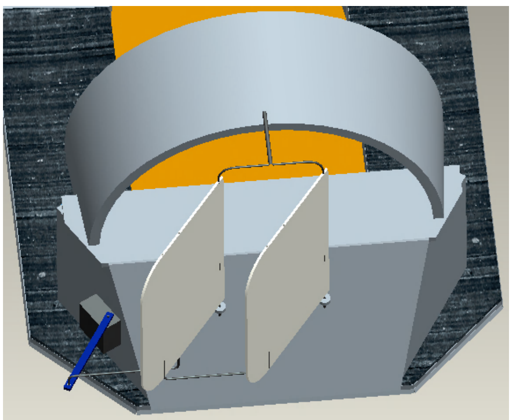

Figure 4.15 Craft is turning 30° left.

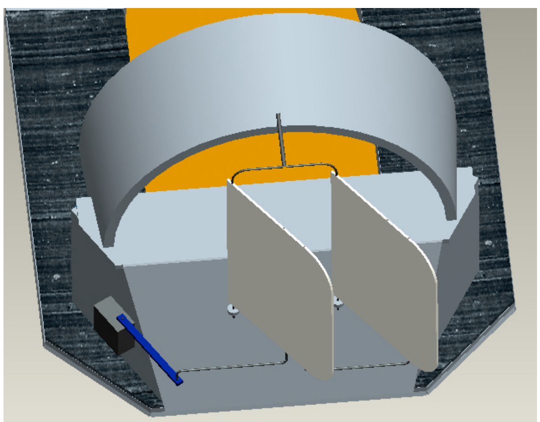

Figure 4.16 Craft is turning 30° right.

CHAPTER FIVE
CONCLUSION

The purpose of this thesis is to investigate pneumatic transport systems to get more efficiency and more performance and to give information about characteristic points of hovercrafts, critical points of designing and controlling.

From thesis results, during designing and manufacturing a simple pneumatic transport system like hovercrafts, the following points should be taken into consideration.

- Hovercraft hulls should be designed light as possible. Therefore, the material selection part is very important during the design of hovercraft hull. Aluminum, fiberglass or plastic should be preferred. Composite material can be preferred for some racing hovercraft. Because the greatest advantage of composite materials is strength and stiffness combined with lightness.

- Working point should be selected very carefully according to the usage aim. Therefore, combination of fan and engine is the second important issue. If the craft is used for racing or for ultimate performance, it should have more thrust. If the craft is used for generally at lower speeds, it should reach the cushion pressure earlier.

- The ideal hovercraft would maximize peak thrust and minimize the thrust and engine speed at design lift.

- Combination of engine and fan should provide the largest possible useable range of thrust.

- Skirt material should be flexible and waterproof such as neoprene-coated nylon. Neoprene-coated nylon is only for light hovercrafts.

- Hover height should be design correctly. If the skirt is too tall, the craft will slide off the cushion and the cushion will deflate or the craft will become unstable.

The next issue on the model will be more focus on controlling. Under supervision of Prof. Dr. Erol Uyar, craft will control from computer by RF modem. Stability tests will be done. The same idea with the Electronic Stability Program (ESP) in the cars will be apply on model hovercraft. Program will check the vehicle direction and when it detects loss of steering control, it will reduce the cushion pressure and increase the drag.

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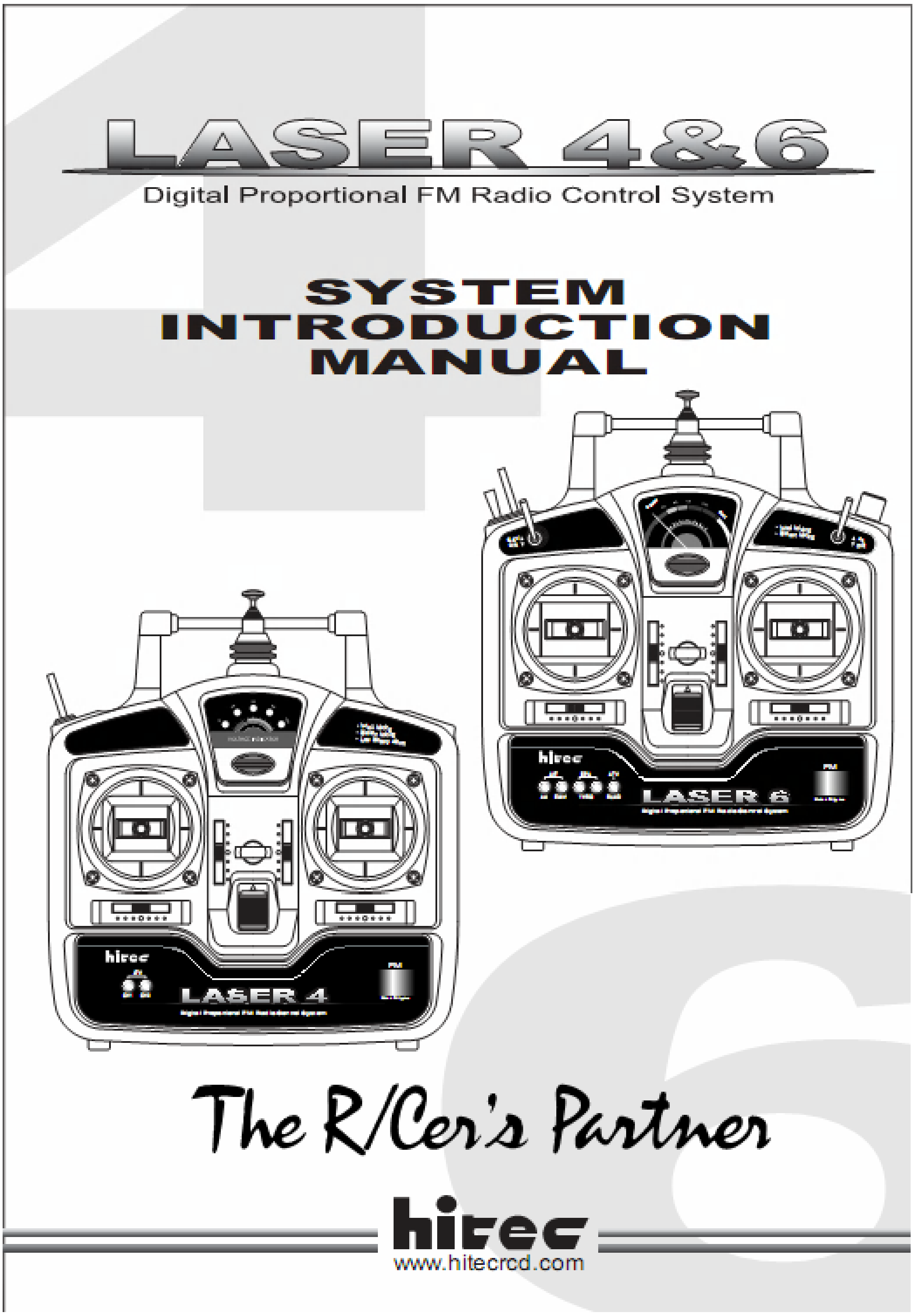
APPENDIX

INFORMATION ABOUT ENGINE AND REMOTE CONTROL



LASER 4&6

SYSTEM INTRODUCTION MANUAL

LASER 4&6 SYSTEM INTRODUCTION MANUAL

5. Product Service Information (for USA & Canada only)

In the event you would require service to your radios, please send the parts to ::

Hitec RCD USA, Inc. Service Department
12115 Paine St.
Poway, CA 92064

Please include your name address and telephone number along
with a brief description of the failure or the work that you are requesting to be done.

6. Precautions

- Always turn your transmitter on first and off last.
- Never operate your system without first performing a proper range check.
- FCC regulation in the USA prohibits changing the crystal in your transmitter. For channel changes send your system to an authorized service/repair center.
- Never fly around or over houses, people or power lines.
- Always charge your batteries before you fly.
- It's a good idea to check your receiver batteries with a tester like the Hitec Power Mate II (part# 44110). This will verify the charge level in your receiver batteries.
- Always fly responsibly and respect the rights of others.
- Make sure your frequency is clear before turning on your system.

Congratulations again and have fun!

LASER 4&6

Digital Proportional FM Radio Control System

CE 0681 ⓘ
Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, The Netherland, Italy, Spain, Norway, Portugal, United Kingdom, Luxembourg, Sweden, Switzerland

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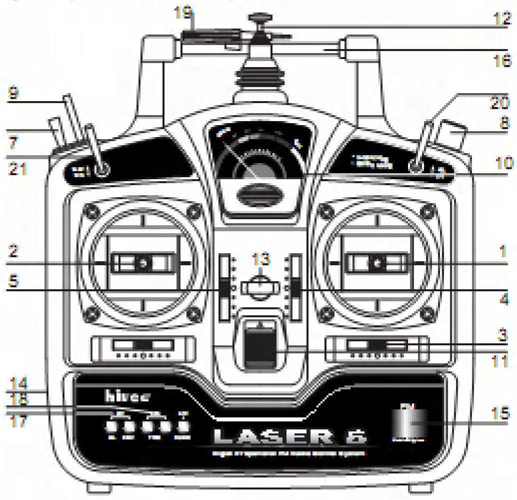
English (영어) **Version 2**

LASER 4&6
SYSTEM INTRODUCTION MANUAL

LASER 4&6 SYSTEM INTRODUCTION MANUAL

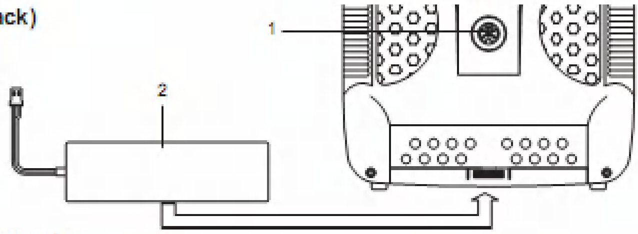
Layout (LASER 6 front)



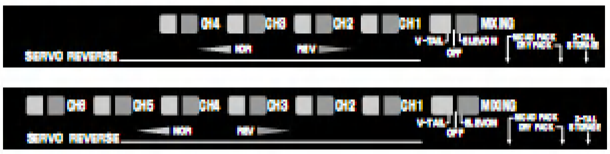
1. Aileron/Elevator stick in MODE II
2. Throttle/Rudder stick in MODE II
3. Aileron trim
4. Elevator trim
5. Throttle trim
6. Rudder trim
7. Landing gear switch
8. Flap variable switch
9. Trainer ON-OFF switch
10. Voltage meter
11. Power switch
12. Rod antenna
13. Neck-strap connector
14. Recharge Jack
15. Crystal
16. Handle
17. Aileron & elevator and rudder adjustable travel volume(A.T.V)
18. Throttle end point adjustment high & low(E.P.A)
19. Screw Driver
20. Aileron & dual rate S/W
21. Elevator dual rate S/W

Layout (LASER 4&6 back)

1. Trainer Jack
2. Nicad-battery



Layout (LASER 4&6 bottom)



LASER 4

LASER 6

C. Specifications

- Power supply : 9.6V (8 cell) Nicad battery or 12V 8cell Dry battery
- Current drain : 150mA
- Output power : 500mw
- Modulation : PPM (FM)

D. Servo Reversing

- The Laser 4/6 FM transmitter is equipped with servo reversing on all channels.
- Leaving the switch in the middle will cause the radio to work erratically so please make sure the switches are all pushed to the furthest end.

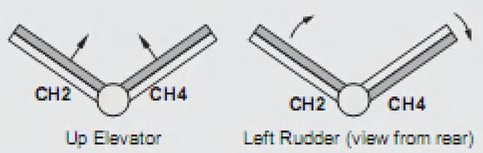
E. Adjustable Travel Volume (A.T.V.)

- CH 1 & CH 2 for Laser 4&6, CH4 for only Laser 6.
- This function adjusts the servo overall travel on CH 1 and CH 2.
- The rate setting is adjustable from 30% to 110%.

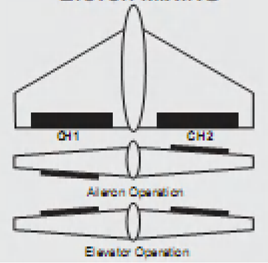
F. Mixing

- The Laser series transmitters are equipped with a switch that will mix ch.2 & ch.4 for V-tail aircraft or ch.1 and ch.2 for Elevon, or common flying wing type aircraft.

V-Tail MIXING

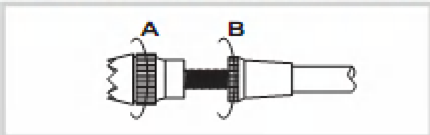


Elevon MIXING



G. Control Stick Adjustment

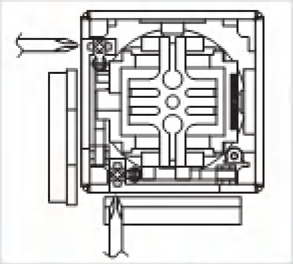
- The length of the non-slip control sticks can be adjusted to suit the requirements of the user.



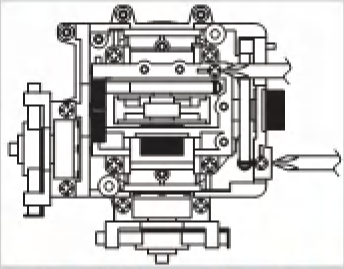
H. Stick Lever Tension Adjustment

- The unique open-stick assembly provides fully adjustable stick tension to adjust the "feel" of the sticks in your hands.
- You may adjust the stick tension of your sticks to provide the "feel" that you like for flying. To adjust your springs, you'll have to remove the rear case of the transmitter. Using a screwdriver, remove the six screws that hold the transmitter's rear cover into position, and put them in a safe place. Gently ease off the transmitter's rear cover and move it to the right side of the transmitter, carefully turning it as you would turn the page of a book. Now you'll see the view shown in the illustration. Using a small Philips screwdriver, rotate the adjusting screw for each stick for the desired spring tension. The tension increases when the adjusting screw is turned clockwise, and decreases for counterclockwise motion. When you are satisfied with the spring tensions, you may close the transmitter. Very carefully reinstall the rear cover. When the cover is properly in place, tighten the six screws.

LASER 4&6 SYSTEM INTRODUCTION MANUAL



Laser 4 Stick Lever Tension



Laser 6 Stick Lever Tension

I. Trim Levers

- The trim levers associated with each control stick are used to correct or (trim-out) the tracking of the aircraft.
- (Caution) Make sure the trims will move the surface past neutral when moved to their extremes. This will assure you have adequate trim control.
- After your plane's first test flight, note the positions of the control surfaces that required trim. Next, center the trims and turn the receiver off. Now adjust the control linkage on the plane so the surfaces are in the same position before the trim levers were re-centered.
- Turn on the radio and receiver and recheck the control surfaces to ensure that all the corrections were applied in the proper direction.

J. Dual Rates (Available on Laser 6 only)

- The Laser 6 offers the user a choice of 2 rates on CH 1, aileron and CH 2, elevator. Dual rates are used to lessen and increase the servo "throw" or movement of the control surface while in flight. For example, a plane traveling very fast will require small servo or stick movements and should be flown on "low rates". While the same plane, flown slower might require more servo throw and could be flown on higher rates.

- Adjusting the Dual Rates

- With the dual rate switch in the low position, you will have full, or 100% throw. When adjusting for a lower rate, move the Aileron dual rate switch up to the higher position. Fully deflect the control surface with the transmitter stick to the left or right and hold it there. Then adjust the "pot" located on the lower left corner of the transmitter case with the provided screwdriver. You will see the control surface move when you turn the pot, adjust it accordingly. Repeat this process to adjust the Elevator dual rate setting.

K. Landing Gear Switch (Available on Laser 6 only)

- The landing gear switch will operate a servo in the CH 5 slot of the receiver. This is typically used for air or mechanically operated landing gear, which is not proportional.

L. End Point Adjustment (E.P.A) (Available on Laser 6 only)

- CH 3. (Throttle)
- This function allows for individual adjustment of the high and low throttle servo end points. Adjust the pots on the face of the radio with the provided screwdriver to position the throttle servo so it does not bind or "buzz" when at high or low stick.

2. Battery Management

A. Transmitter/Receiver battery charging

- The initial charge on your system should be at least 24 hours to ensure a full charge.
- Subsequent charges should be at least 12 - 20 hour.
- It is best to put your system (TX and RX) on charge the night before you plan to use it.
- To charge your batteries, first make sure your transmitter and receiver are off; then connect the wall charger outputs to the charging jack on the transmitter and the charge receptacle on the switch harness or directly to the battery. Make sure the green (TX) and red (RX) lights come on. If it does not, check for proper connection and/or power to the outlet.
- Be careful not to leave your transmitter or receiver battery on charge for more than 24 hours to prevent any damage to the battery or charger.
- Always charge your system before you go out to fly.

B. Battery Spacer

- Pull out the tab of the provided battery spacer first whenever you are taking the battery packs out.
- The size of nicad packs (part# 58207) are smaller than dry battery packs (part# 58101) so plug in the battery spacer into the correct slots so that the battery pack is held tight in its place.

3. Operation

A. Trainer system

- The Laser 4/6 is equipped with a trainer system that allows for master, student control
- Use trainer cord, part# 58310
- When setting up the trainer system, make sure the student radio is set up properly so the trims and servo reversing are the same as the master.
- To activate the trainer system and transfer control to the student pull and hold the trainer switch located on the top let of the transmitter. Releasing the switch will restore immediate control back to the master.

B. Range checking

- Always perform a range check before each operation.
- Perform range check by walking away from the aircraft with the transmitter antenna collapsed.
- You should have complete control from a distance of 60 - 90ft (20 - 30m).
- If the controls are erratic before the minimum distance is reached, do not fly until the problem is resolved.

4. Replacement Parts & Accessories

The following is a listing of replacement parts and accessories available for the Laser radio series from your hobby dealer.

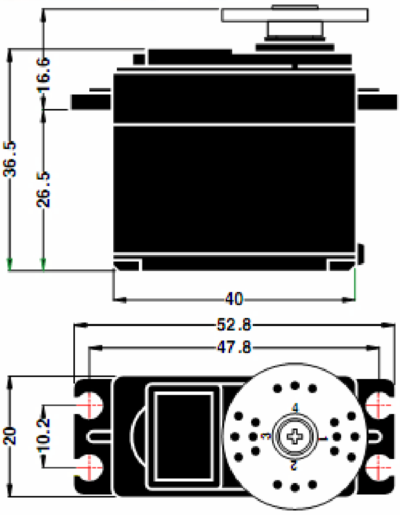
A. TX Antenna (#58005)
B. TX Nicad Battery battery pack (#58101)
D. RX Nicad Battery 600mah (#57401)
E. RX Nicad Battery 1,100mah (#57404)
F. RX Nicad Battery 270mah (#57405)
G. Overnight Charger (#43025)
H. Neck strap (#58311)
I. Trainer cord (#58310)
J. Switch harness (#57215S)
K. Heavy duty gold pin switch harness (#54407)
L. Stick extensions (#56381)
M. Flight Preserver (#58480)

PREPARED BY JUN HEE, LEE
UPDATE:APR 01, 2002

ANNOUNCED SPECIFICATION OF HS-322HD STANDARD DELUXE SERVO

1.TECHNICAL VALUE

CONTROL SYSTEM	:+PULSE WIDTH CONTROL 1500usec NEUTRAL	
OPERATING VOLTAGE RANGE	:4.8V TO 6.0V	
TEST VOLTAGE	:AT 4.8V	AT 6.0V
OPERATING SPEED	:0.19sec/60? AT NO LOAD	0.15sec/60? AT NO LOAD
STALL TORQUE	:3kg.cm(41.66oz.in)	3.7kg.cm(51.38oz.in)
IDLE CURRENT	:7.4mA AT STOPPED	7.7mA AT STOPPED
RUNNING CURRENT	:160mA/60? AT NO LOAD	180mA/60? AT NO LOAD
STALL CURRENT	:700mA	800mA
DEAD BAND WIDTH	:5usec	5usec
OPERATING TRAVEL	:40? /ONE SIDE PULSE TRAVELING 400usec	
DIRECTION	:CLOCK WISE/PULSE TRAVELING 1500 TO 1900usec	
MOTOR TYPE	:CORED METAL BRUSH	
POTENTIOMETER TYPE	:4 SLIDER/DIRECT DRIVE	
AMPLIFIER TYPE	:ANALOG CONTROLLER & TRANSISTOR DRIVER	
DIMENSIONS	:40x20x36.5mm(1.57x0.78x1.43in)	
WEIGHT	:43g(1.51oz)	
BALL BEARING	:TOP/RESIN BUSHING	
GEAR MATERIAL	:2 HEAVY DUTY RESIN	
HORN GEAR SPLINE	:24 SEGMENTS/?5.76	
SPLINED HORNS	:RESULAR/R-C,R-D,R-I,R-O,R-X,SUPER/R-XA	
CONNECTOR WIRE LENGTH	:300mm(11.81in)	
CONNECTOR WIRE STRAND COUNTER	:40EA	
CONNECTOR WIRE GAUGE	:25AWG	



2.FEATURES

LONG LIFE POTENTIOMETER, TOP RESIN BUSHING, 2 HEAVY DUTY RESIN GEARS

3.APPLICATIONS

AIRCRAFT 20-40 SIZE,STEERING AND THROTTLE SERVO FOR CARS, TRUCK AND BOATS

4.ACCESSORY & OPTION

CASE SET/
- HS322T:1EA
- HS322M:1EA
- HS322L:1EA
- PH/T-2 2x30 NI:4EA

GEAR SET/
- HS322G1:1EA
- HS325G2:1EA
- HS325G3:1EA
- HS322G4:1EA
- HS300RB:1EA

HORN SET/
- R-C:1EA
- R-D:1EA
- R-I:1EA
- R-O:1EA
- R-X:1EA
- R-XA:1EA
- WH/W 2.1x15 NI:4EA
- BST 3x5.5:4EA
- NBR 9x6.5x6:4EA

Instructions for Model HFS-06MT/MINI 6S
Hitec 6 Channel Single Conversion Receiver

Thank you for purchasing the Hitec HFS-06MT/MINI 6S single conversion FM receiver. The HFS-06MT/MINI 6S will allow you to enjoy your flight with extreme confidence and satisfaction. This HFS-06MT/MINI 6S utilizes the latest Surface Mount Technology (SMT) to reduce the size and weight. Based on Hitec's latest technology and years of experience building high performance receivers, the HFS-06MT/MINI 6S will provide you with reliable, robust, full range performance for years to come.

Features and Specifications

- 6 channel single conversion FM operation.
- Gold plated pins.
- Ch. 1~6.
- Auto Gain Control
- Auto Shift (For 72MHz/MINI 6S)
- Uses Hitec single conversion crystals.
- Weight : 0.55 oz/(15.5g)
- Size : 1.46x0.98x0.71 in. (37x25x18 mm)
- Input Voltage : 4.3~6.0V

Installation

1. Always turn on the transmitter before turning on the power to the receiver.
2. Always perform a range check prior to the first flight of the day. Check the operation status at least 75 feet away from the receiver with the transmitter antenna fully collapsed.

Changing the Crystal

Your Hitec receiver is "center tuned" and will accept any Hitec single conversion crystal without re-tuning.

*Auto Shift Selection (For 72MHz/MINI 6S)
If you need to match Shift type (Negative or Positive) between Tx and MINI 6S, just by turning OFF and ON of MINI 6S, you can easily synchronize the Shift type (Keep the TX power ON during Auto Shift Selection).

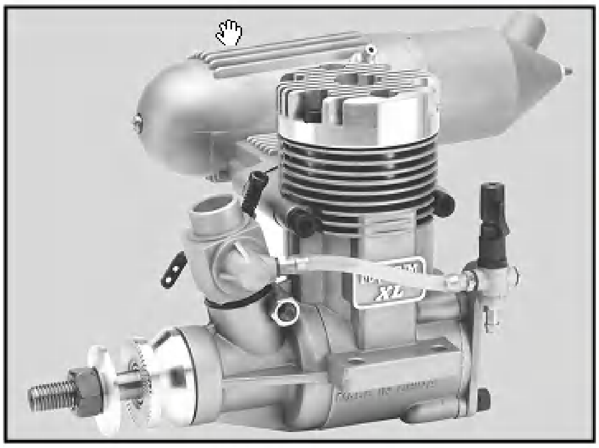
HITEC
www.hitecrcd.com

CE Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Spain, Luxembourg, Norway, Switzerland, United Kingdom, The Netherland, Portugal, Sweden

MADE IN THE PHILIPPINES

MAGNUM XL .61A & .61A*RNV*

Single Cylinder ABC Two Cycle Engine

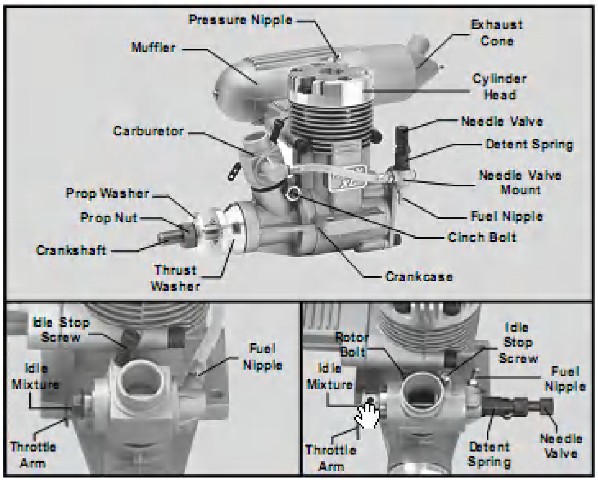


INTRODUCTION

The Magnum XL .61A and .61A*RNV* engines are single cylinder, two cycle engines incorporating ABC piston and sleeve technology for long life and easy break-in. A dual needle carburetor for precise adjustments is standard on both engines. The .61A*RNV* incorporates a cast aluminum rear needle valve assembly for safety. The engine was designed by expert engineers and built by master craftsmen using only the highest quality materials and CNC machinery. These qualities provide the long life and dependability you have come to expect from an engine of this caliber.

BECOMING FAMILIAR WITH THE MAGNUM XL .61A & .61A*RNV*

Before attempting to operate your new engine, please read through this instruction sheet in it's entirety. This will help you familiarize yourself with the features and operation of your new engine. Use the photos below to identify the major component parts of your new engine.



SPECIFICATIONS

Displacement	9.95cc
Bore	24mm
Stroke	22mm
Practical R.P.M.	2,000 - 12,000
Weight (w/Muffler)	21.5oz
Crankshaft Thread Size	5/16 - 24

WARNING!

Magnum model engines will consistently give you dependable performance and reliability and will be a source of satisfaction and pleasure if you follow these instructions as to the engine's proper and safe use. Do not let pleasure turn into injury and/or tragedy! You alone are responsible for the safe operation of your engine, so act sensibly and with care at all times. This Magnum model engine is not a toy. It is a precision built machine whose power is capable of causing serious injury to yourself and others if abused, misused or if you fail to observe proper safety precautions while using it.

- Keep spectators, especially small children, at least 20 feet away from the engine while it is running.
- Mount the engine securely in the airplane or on a suitable engine test stand to run the engine. Follow the mounting instructions in your kits instruction manual or on the plans for individual mounting recommendations. Do not clamp the engine in a vise to test run it.
- Use the recommended size propeller and follow the proper procedure for mounting the propeller. Use the correct size wrench to tighten the propeller nuts. Do not use pliers.
- Inspect the spinner, propeller and propeller nut on a regular basis, looking for any signs of nicks, cracks or loosening.
- To stop the engine, adjust the throttle linkage to completely close the throttle barrel and therefore cut off the air supply. You can also pinch the fuel line to stop the engine, but only if it is accessible. Do not throw anything into the spinning propeller or attempt to use your hands to stop the engine.
- Stand behind the engine when it is running to make any adjustments to the mixture controls. Do not reach over or around the propeller. Do not lean towards the engine. Do not wear loose clothing or allow anything to be drawn into the spinning propeller when the engine is running.
- If you need to carry your model while the engine is running, be conscious of the spinning propeller. Keep the airplane pointed away from you and others.
- Do not use tight fitting cowls or oversized spinners as these can impede airflow over the engine and result in overheating and damage to the engine.

INSTALLATION

❑ **Engine Orientation**

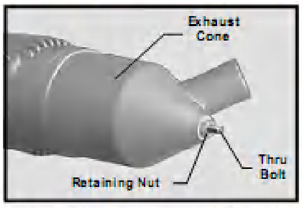
The Magnum XL .61A and .61A*RNV* can be orientated in any position on the firewall. Keep in mind that when the engine is mounted inverted, carburetor adjustments will need to made differently and the fuel tank may need to be lowered. (See tank size and orientation to carburetor on next page).

❑ Engine Bolts and Firewall Requirements

The engine should be mounted to a heavy duty glass filled nylon mount or an integrated hardwood beam mount. Use only high quality steel cap screws and related hardware to mount the engine to the motor mount. The firewall in the airplane should be aircraft grade 5-ply plywood and be no less than 1/4" thick. The firewall should also be reinforced to meet the torque and weight of the engine.

❑ Muffler Installation

The muffler is mounted to the engine using the two socket cap screws, split washers and one of the two gaskets provided. The second gasket should be kept as a spare. Tighten both screws securely to prevent the muffler from loosening during flight. The exhaust cone on the rear half of the muffler is adjustable to better match the installation of your particular application. To adjust the cone, loosen the retaining nut using a small wrench. Rotate the cone to the desired angle then tighten the retaining nut completely while holding the thru bolt in place, from the front of the muffler, using a flat blade screwdriver. It is important to tighten the retaining nut completely to prevent the cone from rotating during flight.



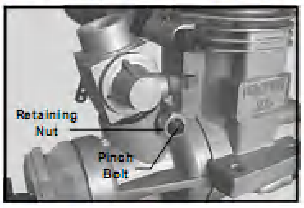
❑ Tank Size and Orientation to Carburetor

Ideally the stopper in the fuel tank should be even with the high speed needle valve or just slightly below the high speed needle valve. Most models will only allow the fuel tank to be mounted higher than the ideal location. A fuel tank that is positioned higher than the ideal location usually doesn't pose any problem except when it is mounted excessively higher and/or used in conjunction with an inverted mounted engine or during extreme aerobatic flight. If mounting your engine inverted it is advised to lower the fuel tank so the stopper is slightly below the high speed needle valve. Doing this will prevent fuel from siphoning into the engine and flooding it when the fuel tank is full. If you cannot lower the fuel tank far enough, we suggest lowering it as far as can be allowed in your particular application.

The size of the fuel tank used should be 10oz. - 14oz. depending on the model and the length of flights desired. Use of a 14oz. tank will provide between 15 - 20 minutes of run time at full throttle. Use of a fuel tank any larger than 14oz. can lead to excessive leaning of the engine during flight and is not recommended.

❑ Carburetor Installation

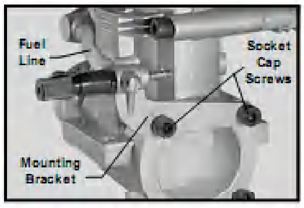
The carburetor is held in place using the pinch bolt and retaining nut already installed in the crankcase. Slide the base of the carburetor into the crankcase, being careful to keep the carburetor perpendicular to the front of the engine. With your thumb, push down on the carburetor firmly so the base of the carburetor sets completely into the crankcase and the carburetor o-ring seals the gap between the two. While holding the carburetor in place, tighten the retaining nut to draw the pinch bolt in place.



Note: Do not overtighten the retaining nut. The nut only needs to be tightened enough to keep the carburetor from turning in the crankcase. Overtightening the nut can cause severe damage to the base of the carburetor.

❑ Rear Needle Valve Installation

The rear needle valve assembly is held in place using the two socket cap screws and two split washers provided with the assembly. To mount the assembly, remove the two upper backplate screws, set the assembly in place, then install the two screws and split washers provided with the assembly. Tighten the screws completely. Install the provided length of silicon fuel line between the needle valve assembly and the carburetor. The fuel pick-up line from your fuel tank will connect to the larger brass nipple on the needle valve assembly.



❑ Needle Valve Extension

If an extension is required to adjust the high speed needle valve, use a 1.5mm diameter wire of the necessary length. Loosen the set screw in the side of the needle valve, insert the wire into the end of the needle valve and tighten the set screw firmly. If the extension is more than 3" long we recommend supporting the outer end of the extension to prevent excessive vibration.

❑ Idle Stop Screw

The idle stop screw holds the throttle barrel in the carburetor body on the XL .61A*RNV*. On the .61A, the rotor bolt holds the throttle barrel in the carburetor body. On both engines, the idle stop screw adjusts the closure of the throttle barrel. We recommend that the throttle barrel be allowed to close completely so the engine can be shut off using your radio transmitter. Turning the screw clockwise will cause the barrel to stay open more. Turning the screw counterclockwise will allow the barrel to close more. Do not turn the screw any further out than necessary to allow the throttle barrel to fully close.

❑ Propeller Installation

Note: Before installing any propeller it must be properly balanced. Running an engine, especially of this size, using an improperly balanced propeller can lead to excessive vibration causing excessive stress and wear on both the engine and the airframe. Balance the propeller using the recommended method of the propeller manufacturer. Several products are available to properly balance propellers. Ask your local retailer for more information about these items.

Using a 5/16" drill bit or a prop reamer, drill out the hole in the propeller hub to fit the crankshaft. The crankshaft is 5/16" in diameter. Slide the propeller onto the crankshaft, up against the thrust washer. Slide the propeller washer up against the propeller. Thread the prop nut onto the crankshaft. Completely tighten the prop nut to secure the propeller in place. When tightening the prop nut, use the proper size open end wrench. Do not use pliers.

Note: If you are installing a spinner onto your engine the cone of the spinner must not rub against the propeller. If the spinner cone rubs against the propeller this could lead to propeller damage and eventual propeller failure.

PROPELLER, FUEL & GLOW PLUG

❑ Propeller Recommendation

The diameter and pitch of the propeller needed for the XL .61A and .61A*RNV* will vary greatly depending on the application the engine is used in. The weight, drag and the type of model and how you intend to fly it are all factors in determining the correct size propeller to use. Experimentation will be necessary to find the optimal size propeller for your particular application. Ideally you want a propeller that the engine will turn in the 10,000 - 12,000 R.P.M. range, yet power the airplane sufficiently. Using a propeller that is too small will cause the engine to run at too high an R.P.M. Using a propeller that is too large will cause the engine run at too low an R.P.M. and cause it to lug down too much. In both instances this can lead to premature engine wear and eventual failure.

Propeller Size Recommendations		
11 x 7	11 x 8	
12 x 6	12 x 7	13 x 5
Use 12 x 6 for initial break-in procedures		

❑ **Glow Plug Recommendation**

Glow plugs can also make a big difference on the performance of your engine. For the XL .61A and .61A*RNV* we recommend using a hot heat range glow plug intended specifically for two cycle engines. Do not use a cold heat range plug. This can lead to erratic engine runs and eventual engine wear and failure.

❑ **Fuel Recommendation**

Fuel can make a big difference in the way your engine performs. We recommend using two types of fuel with the XL .61A and .61A*RNV*. For the break-in period you must use a fuel containing no more than 10% nitro methane and no less than 20% Castor Oil lubricant. Use of fuel containing more than the recommended percentage of nitro methane or any synthetic lubricants will cause the engine to run too hot and result in excessive wear and engine failure in a very short period of time. Once the engine has been adequately broken in (about 1/2 gallon of the recommended break-in fuel), a fuel containing up to, but no more than 15% nitro methane and no less than 16% Castor Oil and synthetic lubricant blended fuel can be used.

Note: We do not recommend using fuels that contain only synthetic lubricants. Synthetic lubricants have a much lower flash point than Castor Oil lubricants. Flash point is the point at which the lubricant begins to actually burn and loses it's lubricating qualities. Using fuels containing a blend of Castor Oil and synthetic lubricants results in an engine that runs cooler and lasts longer. One lean run using a fuel containing only synthetic lubricants can cause engine failure. Using fuels with a Castor Oil and synthetic blend of lubricants greatly reduces this chance.

HIGH & LOW SPEED NEEDLE VALVES

❑ **High Speed Needle Valve**

The high speed needle valve is used to meter the air/fuel mixture at full throttle. Turn the needle clockwise to lean the mixture or turn the needle counterclockwise to richen the mixture. When you start the engine for the very first time the needle valve should be turned in completely, then backed out 2-1/2 turns. When you start the engine after that, leave the needle valve in the same position it was in when you shut down the engine.

❑ **Low Speed Needle Valve**

The low speed needle valve regulates the air/fuel mixture at idle and during transition from idle to full throttle. Turn the idle mixture screw clockwise to lean the mixture. Turn it counterclockwise to richen the mixture. The idle mixture screw is preset from the factory, but minor adjustments may need to be made. To reset the mixture screw to the factory setting open the carburetor barrel completely. While holding the barrel open, for the XL .61A*RNV* turn the mixture screw in until it stops. From this point, turn the mixture screw out 4-1/2 turns. For the XL .61A turn the mixture screw out until it stops. From this point, turn the mixture screw in 3-1/2 turns. These are the factory settings for each engine.

STARTING PROCEDURE

The XL .61A and .61A*RNV* can be started using an electric starter or they can be started by hand. For safety and ease of starting, especially when the engine is new, we recommend using an electric starter. The following two procedures should be done with the power to the glow plug off.

❑ **Starting with an Electric Starter**

When using an electric starter it is not necessary to prime the engine. The starter turns the engine over fast enough that the engine draws fuel on it's own. Priming the engine prior to using an electric starter can cause the engine to "hydro-lock" or flood. This is a result of too much fuel in the engine before it actually fires. Turning the engine over with an electric starter while the engine is flooded can cause extreme damage to the engine and/or cause your propeller assembly to come loose. Turn the propeller through the compression stroke one time by hand to check for a hydro-locked state before applying the starter.

❑ **Starting by Hand**

When starting the engine by hand always use a chicken stick. Never just use your hand or serious injury could result. To make the engine easier to start by hand it should be primed. This is done by opening the carburetor completely and choking the engine by putting your finger over the carburetor opening. With the carburetor choked, "pull" the propeller through the compression stroke 2 - 3 times. This will draw fuel into the engine. Remove your finger and pull the propeller through the compression stroke once to check for a hydro-locked condition.

BREAK-IN PROCEDURE

*Note: The XL .61A and .61A*RNV *are ABC engines. The cylinder sleeve is tapered at the top, causing severe resistance when the piston moves through the top of the stroke.* This is normal. *When the engine heats up to operating temperature, this resistance will decrease and the proper clearance will be achieved. The break-in procedure will guide you through the steps necessary to properly break-in your new ABC engine. Please follow the steps closely.*

The break-in process allows the engine parts to perfectly fit to each other and properly protect each part from premature wear. The engine should be broken in using a fuel that contains no more than 10% nitro methane and no less than 20% Castor Oil lubricant. Synthetic lubricant fuels should not be used during the break-in procedure. For the break-in procedure we recommend mounting the engine into the airplane it will be used in. This way the muffler, fuel tank and throttle linkage can all be tested in combination with the engine. If your airplane uses a cowling, it should be removed during the break-in procedure.

❑ 1) Turn the high speed needle valve out 2-1/2 turns from the fully closed position.

❑ 2) If you are using an electric starter to start the engine, follow the procedure in the previous section. If you are starting the engine by hand, follow that procedure in the previous section.

❑ 3) Open the throttle barrel to approximately 1/4 throttle. Connect the power to the glow plug. Start the engine using an electric starter or by hand. If starting by hand you will need to vigorously flip the propeller through the compression stroke several times before the engine will start.

❑ 4) Once the engine starts, open the throttle barrel to about 1/2 throttle. You may need to lean the high speed needle valve in about 1/4 turn to keep the engine running at half throttle.

❑ 5) After the engine has been running about 1 minute, remove the power from the glow plug. Advance the throttle barrel to full throttle. Adjust the high speed needle valve so that the engine is running very rich. You should notice excessive white smoke coming from the exhaust. Let the engine run for approximately 10 minutes then stop the engine.

❑ 6) Let the engine cool for approximately 10 minutes then restart it. Set the high speed needle valve mixture to a slightly leaner setting, about 1/4 turn more in. Let the engine run for about 5 minutes at this setting then stop the engine and let it cool for approximately 10 minutes.

❑ 7) Repeat the procedure in step # 6, while leaning the needle valve slightly more each time. In all, you should run the engine about a total of 30 minutes of actual running time. After 30 minutes of run time the engine is ready for flight. Fly the airplane with the engine set as rich as possible, but with adequate power to fly the airplane. After each flight, lean the mixture slightly. Continue to do this for about 5 flights. At this point the engine should hold a good setting on the high speed needle valve and you can begin to fine tune the needle valve settings to increase performance.

SETTING THE MIXTURE

Now that your engine is broken in, you can set the high and low speed needle valves for optimum performance.

Note: Be careful to never lean the engine out too much. Remember that the lubricants for your engine are suspended in the fuel. If you lean out the fuel mixture too much you will also be lowering the amount of lubricant entering your engine. Less lubricant means more chance of your engine overheating and possible engine failure.

❑ **Setting the High Speed Needle Valve**

❑ 1) Start the engine and remove the power from the glow plug. Allow the engine to warm up for about 1 minute.

❑ 2) After the engine has warmed up slowly lean the high speed mixture until the engine reaches peak R.P.M. After reaching peak R.P.M. richen the mixture slightly until an audible drop in R.P.M. is heard. If you are using a tachometer this should be between a 200 - 300 R.P.M. drop.

❑ 3) With the engine running at full power, carefully lift the nose of the airplane about 45° into the air. The mixture should not become too lean, but you may hear a slight increase in R.P.M. If the engine sags, or loses R.P.M. when you hold the nose up, the mixture is too lean.

Note: R.P.M. will increase about 10% - 30% in the air. This is due to the forward motion of the aircraft as it is flying. Because of this more air is entering the carburetor, at a higher force, and causes the mixture to lean out. Additionally, as the fuel level in the fuel tank goes down, fuel draw becomes more difficult for the engine, especially during aerobatics, thus causing the mixture to go lean. It is imperative that you set the mixture rich while on the ground to compensate for the leaning tendencies that will happen in the air. Always watch the exhaust during your flight. The engine should leave a noticeable white smoke trail at all times. It there is no smoke trail, the engine is running too lean. You should land immediately and reset the mixture.

❑ **Setting the Low Speed Needle Valve**

❑ 1) Start the engine and lean out the high speed needle valve as per the previous steps. Close the throttle until the slowest reliable idle is reached. Allow the engine to idle for about 30 seconds.

❑ 2) Quickly advance the throttle to full. If the engine just stops running as soon as the throttle is advanced, the idle mixture is too lean. With the engine stopped, richen the idle mixture about 1/8 of a turn.

❑ 3) Repeat steps # 1 and # 2 until the engine will transition from idle to full throttle smoothly. Minor hesitation in the transition will be normal.

❑ 4) If you quickly advance the throttle from idle to full and the engine seems to be very rich during transition (i.e. lots of smoke coming from the exhaust), the mixture is too rich. With the engine stopped, lean the idle mixture about 1/8 of a turn.

❑ 5) Repeat steps # 1 and # 4 until the engine will transition from idle to full throttle smoothly. Minor hesitation in the transition will be normal.

MAINTENANCE

❑ Avoid running the engine under dusty conditions. If you are in a dusty environment we suggest using a air filter over the carburetor.

❑ At the end of every flying day, purge the engine of fuel by disconnecting the fuel line and allowing the engine to run dry of fuel.

❑ Use a high quality after run oil in the engine after you have purged the engine of fuel. Inject the oil into the engine through the carburetor and through the glow plug hole.

❑ Wipe the outside of the engine dry using a soft cloth.

❑ Use a fuel filter between the fuel tank and the carburetor.

SERVICE

All Magnum engines returned for warranty service must be within the warranty terms as stated on the warranty card provided with your engine. Do not return the engine to the place of purchase. They are not authorized or equipped to perform warranty work on Magnum products. When requesting warranty service, please observe the following:

☞ Always send the complete engine including the carburetor and muffler. The engine must be removed from the model.

☞ Include a note detailing the problem or service you are requesting. Service cannot be provided without this information. Include your daytime phone number in the event we need more details pertaining to the service requested.

☞ You may request an estimate of services at the time you return your engine for service. An omission of this request implies permission for the Magnum Service Center to service your engine at our discretion.

☞ Include a method of payment for any service charges. If not specified, the unit will be returned to you C.O.D.

☞ Please include a check or money order in the amount of $6.50 to cover postage and handling charges for the return of your engine. Do not send cash.

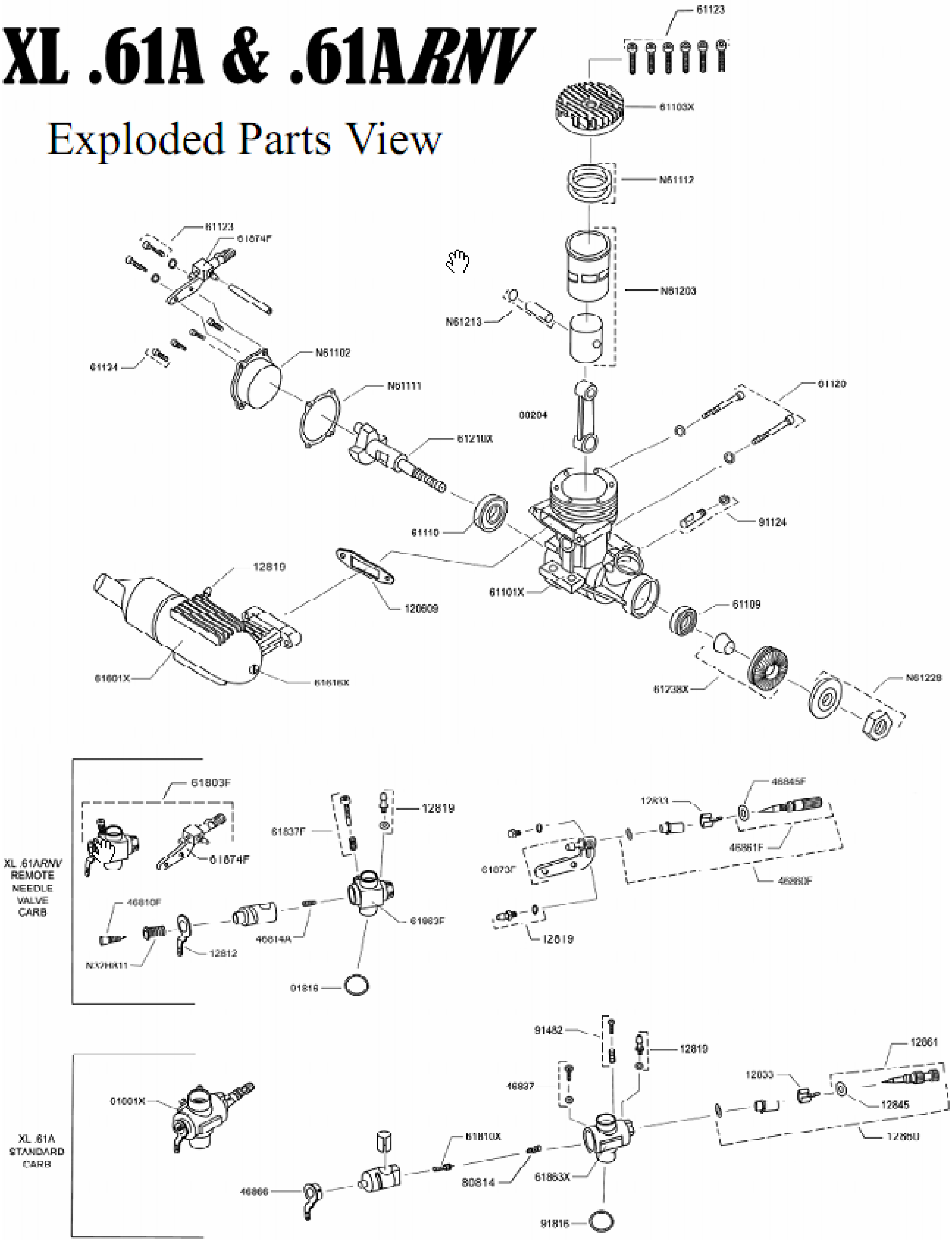
☞ Send the engine to us by United Parcel Service, Federal Express or by Insured Mail. Postage in not refundable. Send to:

Magnum Service Center
18480 Bandilier Circle
Fountain Valley, CA 92728
Phone (714) 963-0329
Fax (714) 964-6236
Email: globalhobby@earthlink.net

MAGNUM

XL .61A & .61A*RNV*

Exploded Parts View



REPLACEMENT PARTS LIST

Part No.	Description	61A	61ARNV
120609	Muffler Gasket	X	X
12812	Throttle Arm		X
12819	Fuel/Pressure Nipple	X	X
12833	Detent Spring	X	X
12845	O-Ring N.V./Idle Needle	X	
12860	Needle Valve Assembly	X	
12861	Needle Valve w/O-Ring	X	
46810F	Idle Needle Set		X
46814A	Carburetor Barrel Spring		X
46837	Carburetor Rotor Bolt	X	
46845F	Needle Valve O-Ring		X
46860F	Needle Valve Assembly		X
46861F	Needle Valve w/O-Ring		X
46866	Throttle Arm	X	
61101X	Case	X	X
61103X	Cylinder Head	X	X
61109	Front Bearing	X	X
61110	Rear Bearing	X	X
61120	Muffler Bolt Set	X	X
61123	Head Bolt/RNV Mount Bolt Set	X	X
61134	Backplate Bolt Set	X	X
61210X	Crankshaft	X	X
61238X	Thrust Washer Set	X	X
61601X	Muffler Assembly	X	X
616116X	Muffler Axial Screw Set	X	X
61801X	Carburetor Assembly	X	
61803F	Carburetor/RNV Assembly		X
61810X	Idle Needle Set	X	
61837F	Idle Stop Screw Set		X
61863F	Carburetor Body		X
61863X	Carburetor Body	X	
61873F	Rear Needle Valve Bracket		X
61874F	Rear Needle Valve Assembly		X
80204	Connecting Rod	X	X
80814	Carburetor Barrel Spring	X	
91124	Carburetor Retaining Bolt	X	X
91482	Idle Stop Screw	X	
91816	Carburetor O-Ring	X	X
N32H811	Throttle Arm Lock Nut		X
N61102	Backplate	X	X
N61111	Backplate Gasket	X	X
N61112	Head Gasket Set	X	X
N61203	Piston & Cylinder Set	X	X
N61213	Wrist Pin Set	X	X
N61228	Prop Nut/Washer Set	X	X

TROUBLESHOOTING GUIDE

PROBLEM	CAUSE	SOLUTION
1) Engine does not start	A) Failed glow plug B) Glow Starter not charged C) Engine not being turned over fast enough D) Old fuel E) Engine flooded with too much fuel	A) Replace glow plug with a new one B) Fully charge glow starter C) Use an electric starter D) Replace with new fuel E) Remove glow plug and expel fuel from cylinder
2) Engine does not draw fuel	A) Idle mixture screw set too lean B) High Speed Needle Valve fully closed C) Hole or crack in fuel lines D) Defective fuel tank	A) Reset idle mixture to factory setting B) Reset high speed needle valve to factory setting C) Replace fuel lines D) Replace fuel tank
3) Engine vibrates excessively	A) Propeller out of balance B) Spinner out of balance C) Engine or motor mount loose	A) Balance propeller B) Balance Spinner C) Check all mounting bolts and tighten securely
4) Engine does not transition	A) Failed and/or wrong type glow plug B) Old and/or wrong type fuel C) Idle mixture set too lean D) Idle mixture set too rich	A) Replace with new recommended glow plug B) Replace with new recommended fuel C) Set idle mixture richer D) Set idle mixture leaner
5) Throttle barrel does not close completely	A) Idle stop screw out of adjustment B) Idle mixture set too lean	A) Turn idle stop screw counterclockwise until barrel closes completely B) Reset idle mixture to factory setting
6) Engine Overheats	A) Engine running too lean B) Cowl too restrictive C) Improper fuel used	A) Richen high speed needle valve B) Open vents in cowling C) Use recommend fuel

STEP OF RUNNING THE CRAFT

1. Before using the hovercraft, charge the batteries one day before.

   - Hitech CG-S32 Charger (TX 9.6VDC / 80 mA) is for transmitter.

   - AD-DC Adaptor (Model: GSD0010600006C, Input 230VAC 50Hz 0.03AMAX, Output: 1.25vdc 600Ma 0.75va) is for glow plug connector.

   - During tests original charger for receiver battery is damaged. Charge the receiver with the charger (4.8VDC / 80mA) shown in Figure A1. It doesn't have stopper. Do not charge battery over 2 hour, otherwise it can explode.

Figure A1. Chargers for transmitter, receiver and glow plug connector.

2. Open the fuel tank tap and full the tank with fuel for model aircrafts. (Figure A2) I used 10% nitro ratio. More nitro means more power.

Figure A2. How to full the tank.

3. Put the receiver battery to its place and connect the cables between receiver and battery (Figure A3).

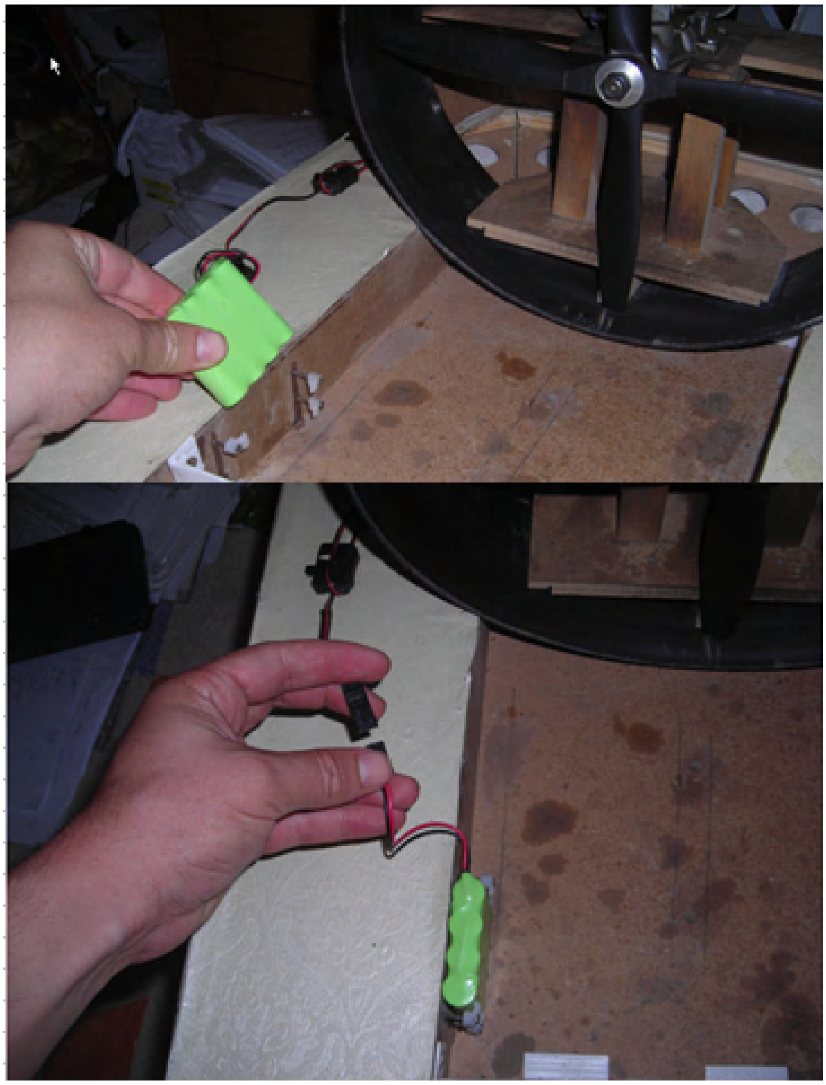


Figure A3. Receiver battery position and cables.

4. Take out the hosepipe from exhaust. Blow air into the hosepipe, until fuel comes into the needle valve (Figure A4). When you see small amount of fuel goes into needle valve, stop blowing air. After that put the hosepipe again on exhaust.

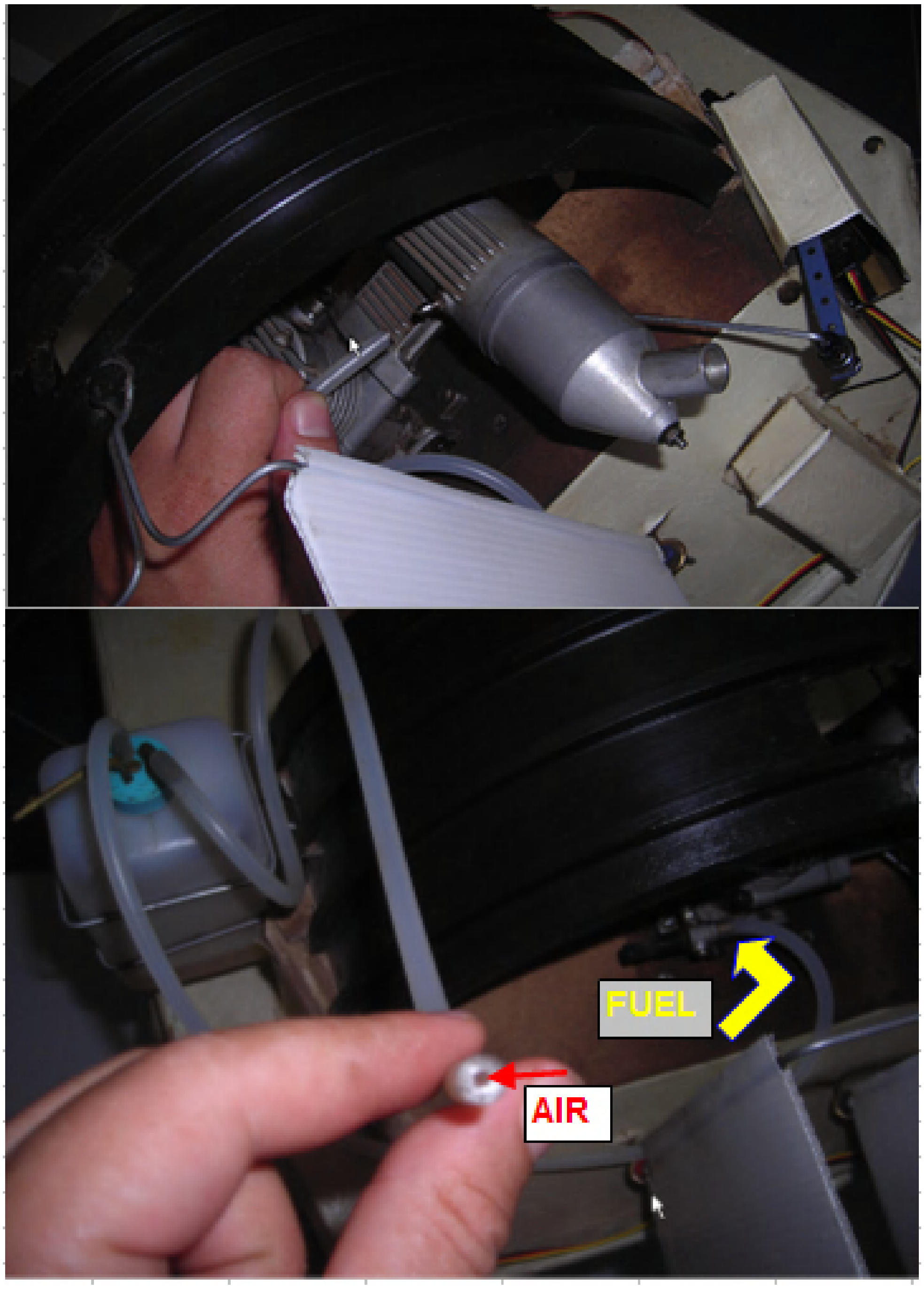


Figure A4 Getting fuel into the needle valve.

5. Place the glow plug on spark plug. Pull the handle on glow plug and push it down on the spark plug.

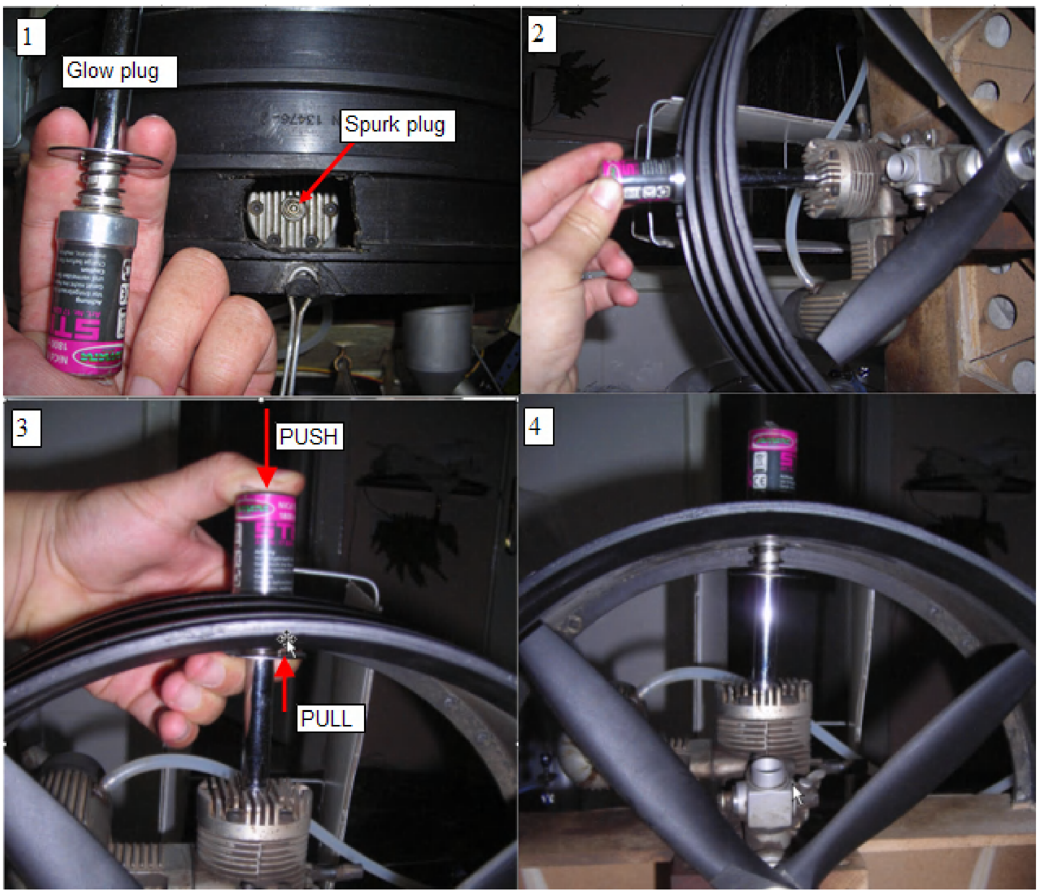


Figure A5. Placing glow plug.

6. Turn on the power switch for receiver.

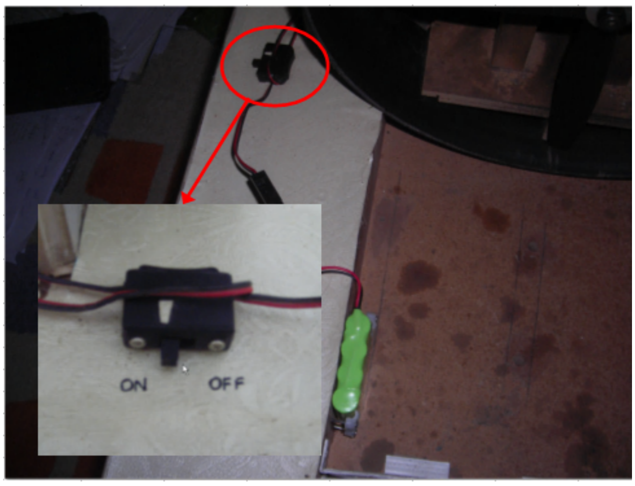


Figure A6 Power switch of receiver

7. Turn on the switch of transmitter.

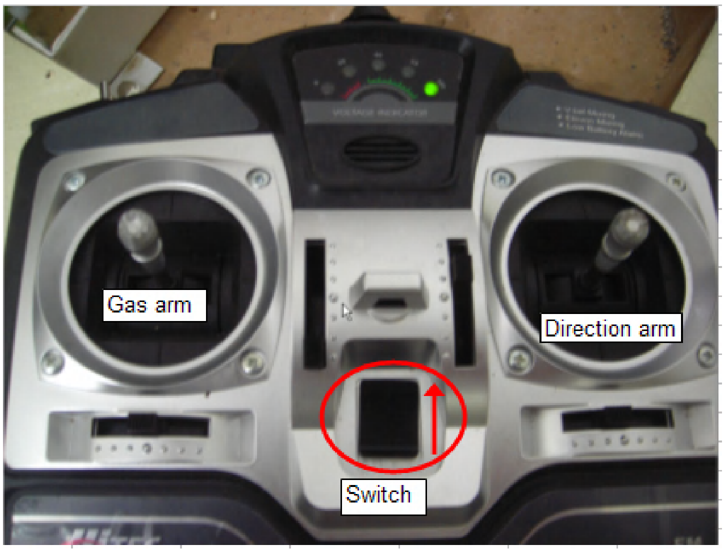


Figure A7. Switch of transmitter

8. Adjust wings direction by fine tuning switch. Wings should be parallel to the direction.

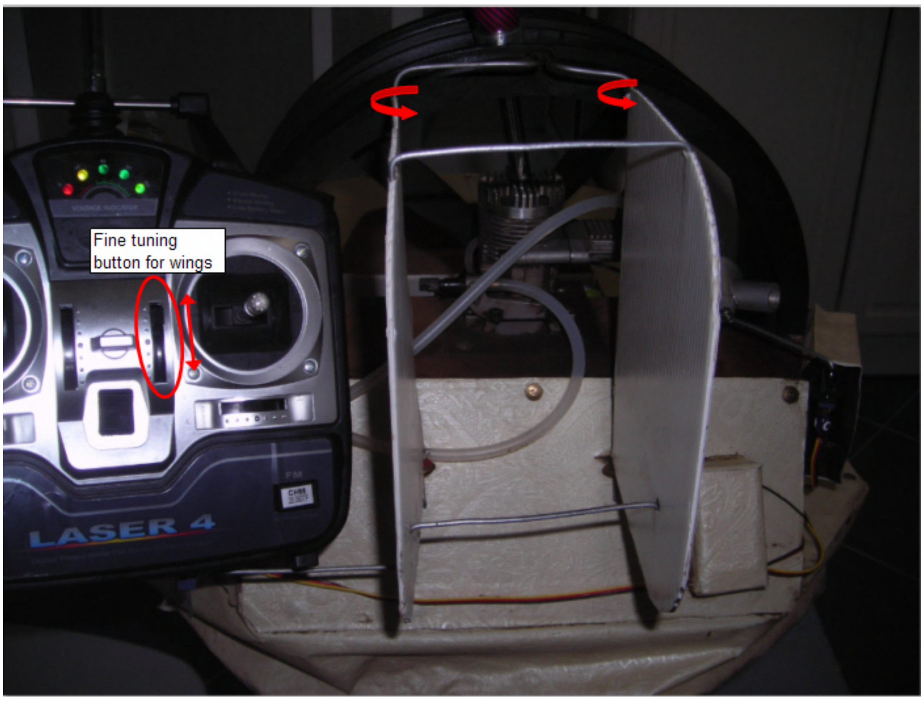


Figure A8. Adjusting wings direction

9. Before running the craft gas fine tuning button should be in the middle and gas arm should adjust to minimum gas. (Figure A9)

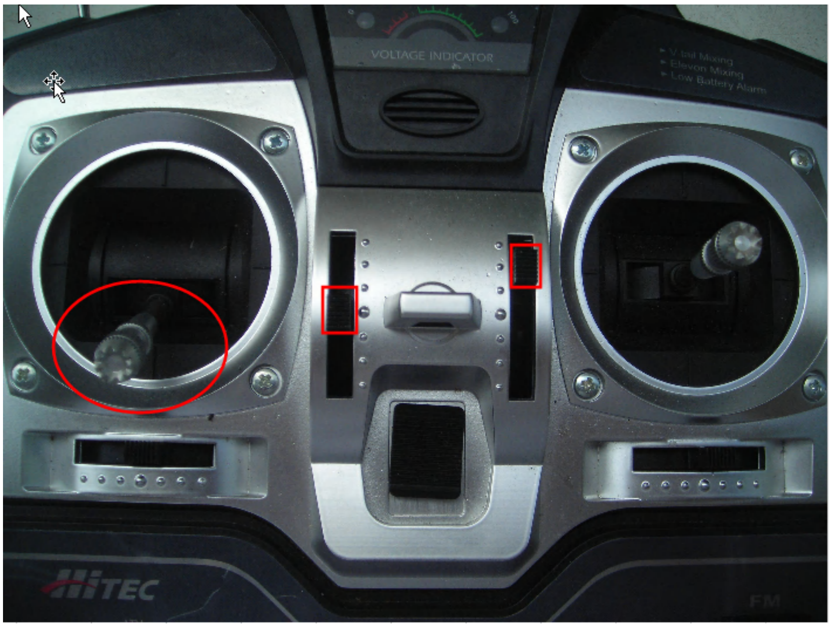


Figure A9 Position of the buttons before running craft.

10. Finally, turn the propeller to the left strongly until engine gets the first motion.

Figure A10 Giving first motion to the engine