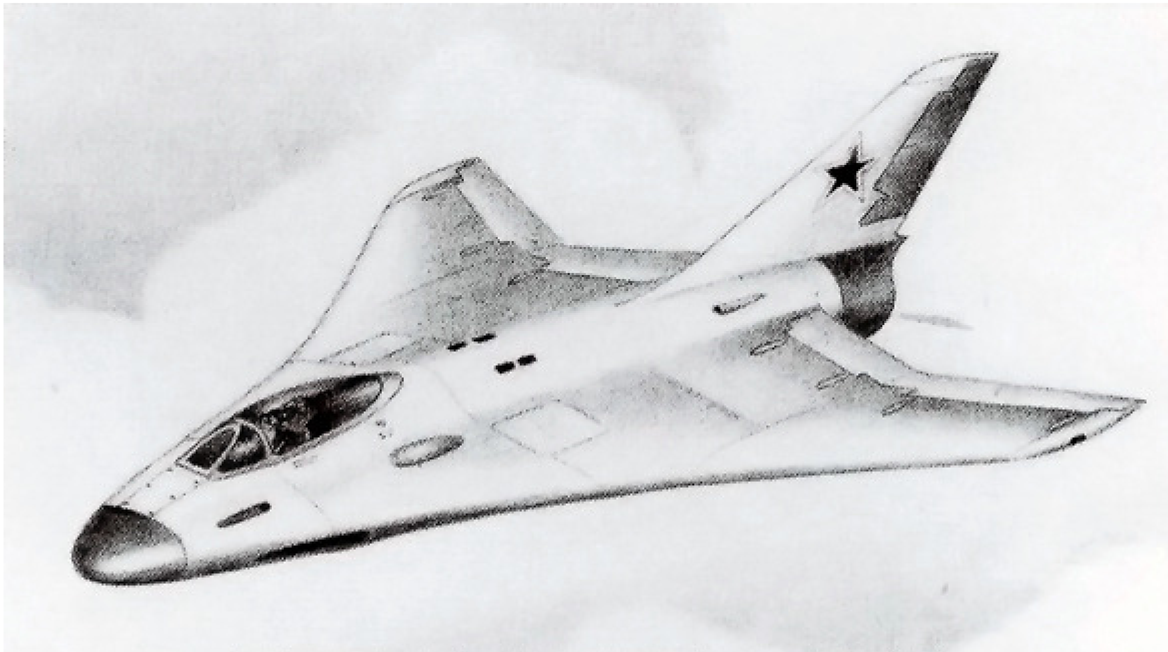
No. 371 JUNE 2017

T.W.I.T.T. NEWSLETTER



Cheranovskij designed the BICh-26 which externally looked very similar to the BICh-24, a tailless delta wing design with a single fin & engine. Several more years where spent refining the design & demonstration models where built, but by then less complex & more readably available design from Mikoyan & Sukhoi where being built & then with the death of Cheranovskij the whole project was cancelled. Source: https://forums.revora.net/topic/77338-bich-26/

T.W.I.T.T.
The Wing Is The Thing
P.O. Box 20430
El Cajon, CA 92021

The number after your name indicates the ending year and month of your current subscription, i.e., **1706** means this is your last issue unless renewed.

THE WING IS THE THING (T.W.I.T.T.)

T.W.I.T.T. is a non-profit organization whose membership seeks to promote the research and development of flying wings and other tailless aircraft by providing a forum for the exchange of ideas and experiences on an international basis. T.W.I.T.T. is affiliated with The Hunsaker Foundation, which is dedicated to furthering education and research in a variety of disciplines.

T.W.I.T.T. Officers:

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Wt/#Issues	FRG	AUSTRALIA	AFRICA
1oz/1	1.75	1.75	1.00
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Meetings are held on the third Saturday of every other month (beginning with January), at 1:30 PM, at Hanger A-4, Gillespie Field, El Cajon, California (first row of hangers on the south end of Joe Crosson Drive (#1720), east side of Gillespie or Skid Row for those flying in).

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PRESIDENT'S CORNER

I got the following message notifying us that one of our longest standing member had recently passed away.

"Davis Tracy here, executor of Mr. William Foshag's estate. Will was an aeronautical engineer employed by Fairchild and involved in Sikorsky aircraft development in the 1950s and 60s. He was a subscriber to T.W.I.T.T. for many years. His interests and passion for flight and physics were expanded through his purchase of Heishman's Mill (circa 1800) in Carlisle PA, where he lived until his recent death on April 27, 2017.

Among his possessions are numerous model aircraft, many still in their original unopened boxes, a Marske P2 T/L glider, and his aeronautical papers and files. I am writing to you to ask if you know of individuals who would wish to acquire his flight-related possessions. It is my duty as his friend and executor to find homes for the things he cherished."

Our condolences to his family and friends. Hopefully I will have an obit for him next month since I am sure it will be quite interesting.

I communicated with Davis letting him know that TWITT as an association didn't have the ability to absorb any of the papers, models or aircraft but that I would put out a query to the membership to see if there were possibilities.

I suggested perhaps the Smithsonian might be interested in the models and P2 or perhaps the Southwestern Museum, while the Library of Congress for the papers and files unless someone else can be found to take what I am to understand is a quite substantial collection.

I will reach out to some specific individuals to see what kind of interest I can generate, but if any of you are interested or know of someone who might be qualified to take some or all of Bill's collection, please let me know as soon as possible.

Andy

LETTERS TO THE EDITOR

Hello Bob,

Hoping you are fine as ever and happily flying your birds over there. If you remember, we've had some correspondence so many years ago, I think way back in 1999 about our mutual interest in the way birds fly. I too am retired and resumed the hobby- definitely a fun way to while away the hours.

Lately, I've experimented with flying small model pterosaur gliders, in a scale close to the little pelican model I've sent you long ago. With the advent of the Internet, this time I'm sending over a plan of one little critter with a very de-stabilizing head -Tapejara Imperator - instead of a model by mail.

Best regards to you and your family.

Rodolfo L. Betita
Capt A320, Cebu Pacific (ret)
Cavite, Philippines

Hello Rudolfo,

Yes, I still have the little pelican model you sent me. The weather has been very windy this spring here in the desert, so I haven't been flying many bird models lately. I have enjoyed hearing from many of my bird-model friends, like yourself, from all over the world. (Italy, S. Africa, Netherlands, England, etc).

I've got some spare balsa wood around, so maybe I'll give your plans a try.

Thanks for the note.

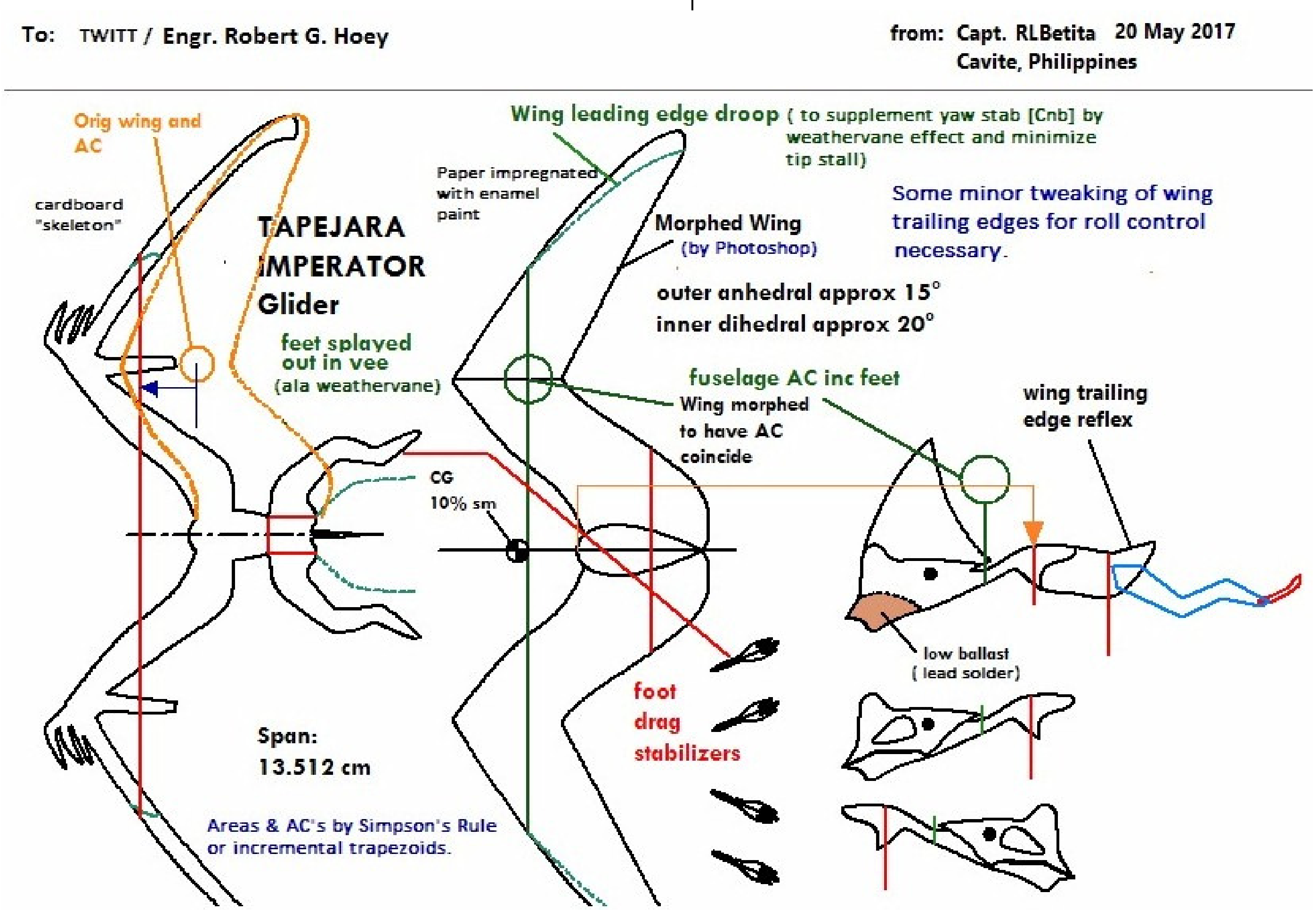
Bob Hoey

Hi Bob,

Another one for your perusal. From Prof. MacReady (modified).

RLB

(ed. – See next page.)



All:

This is a pleasant surprise, totally unexpected. Scroll down about 80% to "Alumni Spotlight" Great exposure for my website and research!

Regards,

Phil Barnes

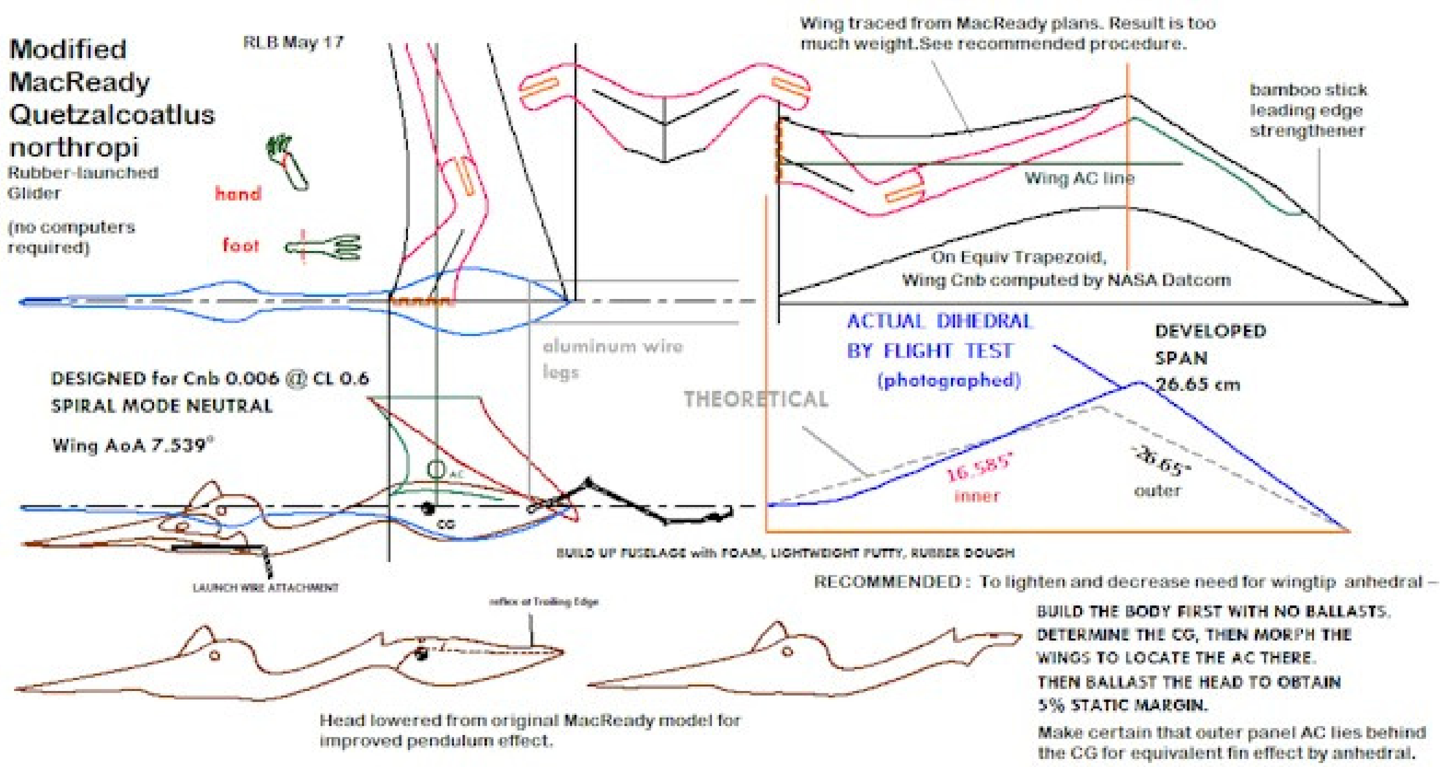
J. Philip Barnes (MSAE '88) has conducted leading-edge studies of dynamic soaring and regenerative-electric flight and is a principal engineer at Northrop Grumman. He was the recipient of the 2016 Gohardani Aerospace Presentation Award and was named Cal Poly Pomona Outstanding Aerospace Engineering Alumni in 2014. Philip mentors several Cal Poly Pomona capstone engineering projects including a project that will be presented by a student team this year at the college's Project Symposium & Showcase. Philip has also authored several SAE and AIAA technical papers and provides his work freely on his website, www.howfliesthealbatross.com.

(ed. – Starting on the next page is an AIAA paper prepared by Phil Barnes who has graciously allowed us to publish it in our newsletter.

This will be the first installment with the rest coming in future issues depending on space available from other material.

I know this is not a flying wing specific topic but I think it is relevant since it is covering the progress being made in propulsion systems that could be adaptive to flying wing aircraft. With all the wing surface area and the new technologies in solar cells, electric propulsion when coupled with the regenerative aspect could be a good combination for a flying wing.

If you have difficulty reading any parts of the article drop me a note and I will send you a hard copy.)



AIAA 2016-4711

Propulsion and Energy Forum
July 25-27, 2016, Salt Lake City, UT
52nd AIAA/SAE/ASEE Joint Propulsion Conference

CrossMark

Principles of High-efficiency Electric Flight

J. Philip Barnes[1]
Pelican Aero Group, San Pedro, CA 90731

To maximize the system efficiency of aircraft electric propulsion incorporating one or more propellers, ducted fans, or open rotors and permanent-magnet (PM) electrical machines working with either a battery or fixed-voltage source, we first model a fixed or variable torque loss and then non-dimensionalize rotational speed, current, and torque. The approach is validated with test data for various machines and voltages. We then solve for and optimize the system efficiency in terms of the non-dimensional parameters and show that a given combination of load torque, rotational speed, and system electrical resistance calls for specific optimal values of battery EMF and motor voltage constant, all solved iteratively with the proposed method. For reduced power at cruise, both theory and data reveal serious losses, well beyond those of "chopping," of the popular method of applying pulse-width modulation (PWM) to the main current. DC-DC conversion is then introduced as a high-efficiency power-conditioning alternative, borrowing from ground-electric-vehicle "regenerative-braking" technology. Here PWM finds a useful and efficient role by operating on a small, auxiliary current to adjust DC-DC converter voltage "boost" or "buck." Finally, the method is applied to optimize the power architecture of a sport-electric aircraft, demonstrating high efficiency at all conditions, including cruise and regeneration.

Nomenclature (S.I. metric units)

α = "actual" factor on battery current
β = "boost or buck" Voltage ratio ~ E_m/E_b
δ = duty cycle ("on" fraction of PWM cycle
E = Circuit-node Voltage, Volts
ESC = Electronic speed control
ε = Electro-motive force, Volts
η = Efficiency, component or system as noted
i = current, Amps
k = EMF constant, Volts/(rad/s) or N-m/Amp
K_v = Voltage constant, RPM/Volt = $30/(\pi k)$
λ = fixed or variable torque loss, N-m
m = motor-generators per battery
ν = speed ratio, $\omega/(\varepsilon_b/k) = k\omega/\varepsilon_b$ = RPM/($K_v \varepsilon_b$)
PM = permanent-magnet, or fixed field strength
PWM = pulse-width modulation
R = resistance, Ohms
RPM = motor rotational speed, revolutions/min
τ = motor shaft torque, N-m
ω = motor rotational speed, rad/s
ψ = specific (non-dim.) torque loss, $\lambda R/(k\varepsilon_b)$

Subscripts

b = battery
m = electrical machine
e = "either path" or "system equivalent"
e = "electrical" (versus shaft) power basis
opt. = optimal
s = "shaft" (versus electrical) power basis
t = time, sec, battery sortie life

I. Introduction

The "regenerative-electric" aircraft[1] (Figure 1) is just one of myriad applications of "permanent-magnet" (PM) motor generators. Such machines enable simple circuit modeling and efficient characterization of their performance. This paper, supported by diverse test data, reviews and renews PM machine theory, illustrates optimization of the battery-motor system at full power, exposes high losses of main-current pulse-width modulation (PWM), and introduces DC-DC conversion for high-efficiency power-conditioning at all conditions including full power, cruise, and regeneration.

Figure 1. "Regen" electric aircraft in ridge lift.

[1] Technical Fellow, AIAA Senior Member

II. Brushed or Brushless Permanent-magnet Motor-generator

The permanent-magnet motor-generator, whether brushed or brushless, and whether motoring or generating, is characterized by the generation of an electro-motive force (EMF), or Voltage, which is proportional by a constant (k) to the rotational speed (ω) and which opposes the battery or other Voltage source interacting with the machine. Here we must not confuse the EMF constant ($k \equiv \varepsilon/\omega$) with units of Volt-sec per radian, or N-m/Amp, with the "Voltage constant" (K_V) of units RPM per Volt. Although we are indebted to the classical brushed machine for a direct derivation[2] of these phenomena, arcing and other limitations of the brushed machine have led to the use of brushless machines for a vast array of applications, including propulsion of ground and flight electric vehicles.

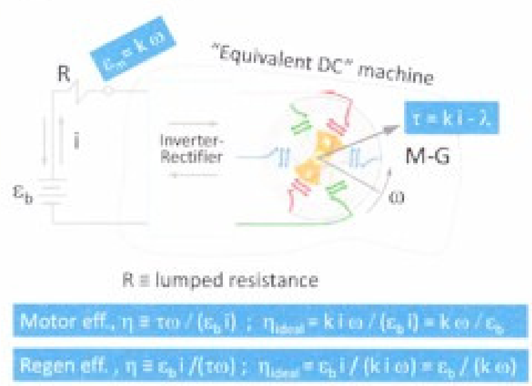


Figure 2. Brushless motor-generator system.

The brushless machine is electronically commutated by an inverter which as a byproduct also provides rectification to enable regeneration. The brushless M-G *as a system* with its inverter-rectifier (Figure 2) has the same two-wire battery interface and the same voltage-speed and torque-current proportionality of a brushed machine.

Thus, we can model the system with two batteries, one fixed and the other variable, "competing" to set the direction and quantity of current (i) in a combined resistance (R). If a fixed Voltage source is used, "battery EMF" is the source voltage, and "battery resistance" becomes zero.

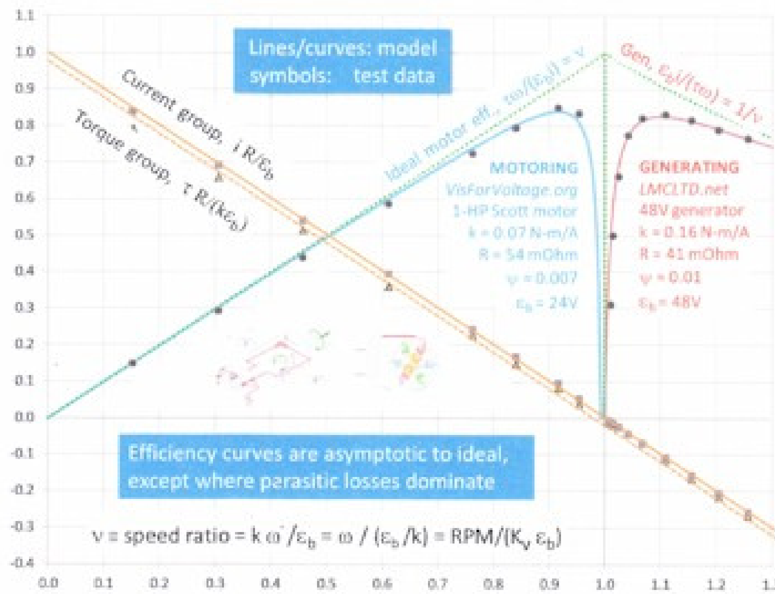


Figure 3. Motor-generator ideal and actual efficiency.

With or without losses, motoring efficiency is given by the ratio of shaft power ($\tau\omega$) to battery electrical power ($\varepsilon_b i$) taken "upstream" of the loss imposed by battery internal resistance (R_b). Given PM machine behavior, we are soon led to an "EMF ratio" ($k\omega/\varepsilon_b$) which is also a "speed ratio" or non-dimensional speed [$\omega/(\varepsilon_b/k)$ = RPM/($K_v\varepsilon_b$)]. We designate this fundamental parameter (ν), noting that when it is unity, the EMF of the motor-gen matches that of the battery, with current at zero and torque near zero. This leads us to non-dimensional current (iR/ε_b), non-dimensional torque [$\tau R/(k\varepsilon_b)$] and non-dimensional torque loss $\psi \equiv [\lambda R/(k\varepsilon_b)]$, both of which take the torque (τ) or torque loss (λ) as a ratio with ideal stall torque ($k\varepsilon_b/R$) where (ω=0). The non-dimensional torque loss typically ranges from perhaps 0.005 at "sport" scale to 0.020 at model scale, depending also on design.

As was shown in Figure 2, *ideal* motoring efficiency and speed ratio (ν) are fundamentally one and the same, and *ideal* generating efficiency is the inverse of speed ratio. In practice, parasitic losses dominate near unity speed ratio, yielding the characteristic curves of Figure 3. All PM machines will show similar behavior, but none can exceed the theoretical limits of the "wedges" (dashed blue lines) in the figure, where we imagine ideal motor efficiency to fall immediately from unity to zero at unity speed ratio. Machines with the highest motoring and generating efficiencies will exhibit curves penetrating more deeply into the corners of the "wedges." We next apply the method to condense test data[3] taken over a wide range of voltages for a brushless-outrunner of model-aircraft scale (Figure 4). The condensation appears at the lower-right corner of the figure.

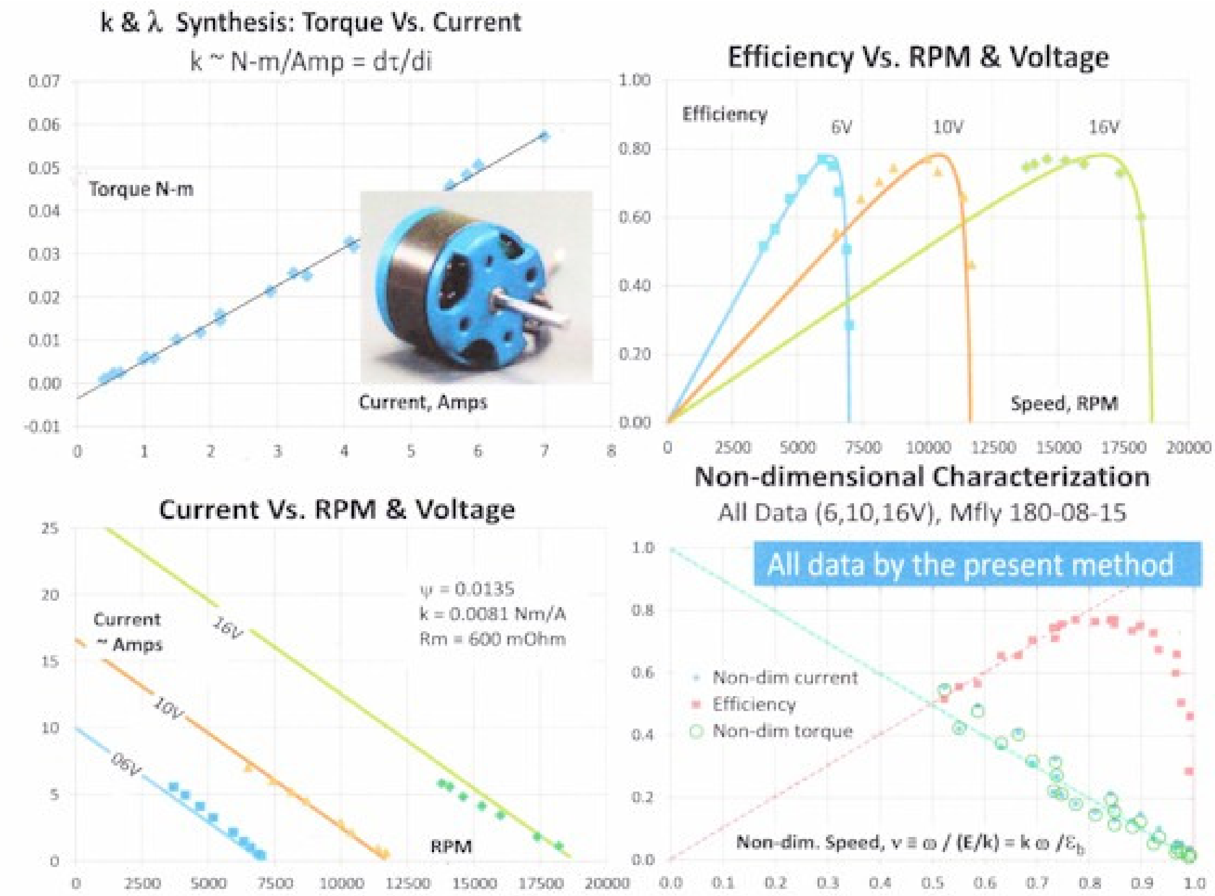


Figure 4. Condensation of brushless "Mfly" motor test data for a range of power-supply Voltages.

III. System efficiency at full power with one or more motor-generators

Figure 5 shows our circuit model for either a single battery or fixed-voltage supply of EMF (ε_b) working with (m) brushed or "brushless-with-inverter-rectifier" motor-generators (recall Figure 2). Battery internal resistance (R_b) is "downstream" of its EMF and the terminal Voltage (E_b) equals that (E_m) of the motor-generator(s), each downstream of a brushed-armature or brushless-two-phase resistance (R_m). For now, we assume full power (no power conditioning).

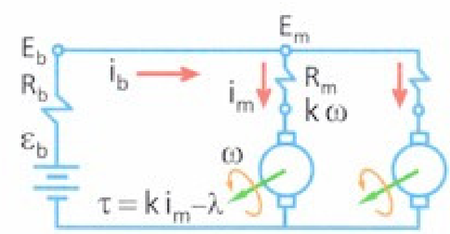


Figure 5. System circuit model.

Our first attempt to model the system with non-dimensional battery current (i_b) was problematic; instead non-dimensionalizing motor current (i_m) gained success. As a result, the use of an "either path" resistance ($R_e \equiv mR_b+R_m$) supplanted the use of a "system" resistance [$R_s \equiv R_b+(R_m/m)$]. The "either path" resistance is found by tracing Voltage from "upstream" of battery resistance to downstream of either motor resistance, noting ($i_b = m\, i_m$).

Defining non-dimensional speed ($\nu \equiv k\omega/\varepsilon_b$), current ($i_mR_e/\varepsilon_b$), torque [$\tau R_e/(k\varepsilon_b)$], torque loss [$\psi \equiv \lambda R_e/(k\varepsilon_b)$], and system motoring or generating efficiency [$\eta_s \equiv (\tau\omega)/(\varepsilon_b i_m)$ or $(\varepsilon_b i_m)/(\tau\omega)$] on a per-machine basis, we find these parameters to be inter-related by Eqs. (1). Next setting the derivative of efficiency with speed ratio to zero, we obtain the motoring and generating *system-optimal* efficiencies and *system-optimal* speed ratios of Eqs. (2). Here, system and component performance are one and the same if the "battery" is a fixed-Voltage source. And for regeneration, both torque and current are negative, as both torque loss and the rotation-speed vector remain positive.

AVAILABLE PLANS & REFERENCE MATERIAL

Coming Soon: <u>Tailless Aircraft Bibliography</u>
Edition 1-g

Edition 1-f, which is sold out, contained over 5600 annotated tailless aircraft and related listings: reports, papers, books, articles, patents, etc. of 1867 - present, listed chronologically and supported by introductory material, 3 Appendices, and other helpful information. Historical overview. Information on sources, location and acquisition of material. Alphabetical listing of 370 creators of tailless and related aircraft, including dates and configurations. More. Only a limited number printed. Not cross referenced: 342 pages. It was spiral bound in plain black vinyl. By far the largest ever of its kind - a unique source of hardcore information.

But don't despair, Edition 1-g is in the works and will be bigger and better than ever. It will also include a very extensive listing of the relevant U.S. patents, which may be the most comprehensive one ever put together. A publication date has not been set yet, so check back here once in a while.

Prices: To Be Announced

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VIDEOS AND AUDIO TAPES

(ed. – These videos are also now available on DVD, at the buyer's choice.)

VHS tape of Al Bowers' September 19, 1998 presentation on "The Horten H X Series: Ultra Light Flying Wing Sailplanes." The package includes Al's 20 pages of slides so you won't have to squint at the TV screen trying to read what he is explaining. This was an excellent presentation covering Horten history and an analysis of bell and elliptical lift distributions.

Cost: $10.00 postage paid
Add: $ 2.00 for foreign postage

VHS tape of July 15, 2000 presentation by Stefanie Brochocki on the design history of the BKB-1 (<u>B</u>rochocki,<u>K</u>asper,<u>B</u>odek) as related by her father Stefan. The second part of this program was conducted by Henry Jex on the design and flights of the radio controlled Quetzalcoatlus northropi (pterodactyl) used in the Smithsonian IMAX film. This was an Aerovironment project led by Dr. Paul MacCready.

Cost: $8.00 postage paid
Add: $2.00 for foreign postage

An Overview of Composite Design Properties, by Alex Kozloff, as presented at the TWITT Meeting 3/19/94. Includes pamphlet of charts and graphs on composite characteristics, and audio cassette tape of Alex's presentation explaining the material.

Cost: $5.00 postage paid
Add: $1.50 for foreign postage

VHS of Robert Hoey's presentation on November 20, 1999, covering his group's experimentation with radio controlled bird models being used to explore the control and performance parameters of birds. Tape comes with a complete set of the overhead slides used in the presentation.

Cost : $10.00 postage paid in US
$15.00 foreign orders

FLYING WING SALES

BLUEPRINTS – Available for the Mitchell Wing Model U-2 Superwing Experimental motor glider and the B-10 Ultralight motor glider. These two aircraft were designed by Don Mitchell and are considered by many to be the finest flying wing airplanes available. The complete drawings, which include instructions, constructions photos and a flight manual cost $140, postage paid. Add $15 for foreign shipping.

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