THE INFLUENCE OF DEMOISELLE AIRCRAFT ON LIGHT AND GENERAL AVIATION DESIGN

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Abstract

In 1907 aviation pioneer Santos-Dumont had the idea of building a very light airplane. He designed and built No.19, the Demoiselle, an aircraft with a 6 meter wing span and a 24 HP engine of his own design. The Demoiselle was very successful in flying, became very popular and its development continued as No.20, No.21 and No.22 (his last airplane). The influence of the Demoiselle on design principles of light aircraft and general aviation were studied in this work, using statistical entropy. The designs number 20 and 22 may be considered dominant and influenced the design principles of light aircraft and general aviation,

1 Introduction

Scaling design-level industry needs to take into account the rate of diffusion of the relationship between product characteristics. On the other hand, the coding of the design principles associated with the emergence of a dominant design involves a principle of divergence of particular design that was developed in the past.

This is only a point of curve evolution and future direction of this evolution can generally be predicted by knowledge of his past. In other words, we must often go beyond the past to have a clear idea of the future. It is important that the engineer understands the historical development of their specialty.

Information theory was first mentioned in an article titled "The Mathematical Theory of Communication." The main purpose of this study is to address the problem of information transmission through a noisy channel. Entropy is based on the statistical probability distribution and produces satisfactory results in the study of phenomena rolling level of any population of heterogenic entities (Saviotti, 1988 [5]). Systems such as biological evolution, growth, image reconstruction and technological developments in specific sectors of automotive and aviation can be analyzed using the Statistical Entropy.

Utterback and Abernathy, 1975 [9] have proposed the concept of life-cycle to describe technological evolution of a product development design. If a certain technology has been established for a long period of time without producing major innovations, we may conclude that the entropy or the uncertainty of the period is very low and the competitors, if any, borrowed innovations imposed in the past to the technology. At the beginning of the life cycle of a product, a variety of new products are being developed. The competition between designs is eventually resolved with the emergence of a design considered dominant. Later all the innovation will focus on process improvements and increases the product with reference to that dominant design.

The concept of trajectory can be evaluated as a comparison dynamics of a dominant design. Nelson and Winter, 1977 [4] emphasized that these trajectories relate not only periods during which the basic principles remain unchanged technology, but also ordered phases (scaling) design. A prime example of a series of models ordered in civil aviation has been representing the trajectory of the aircraft with piston engines and propeller passenger transport, designed and built by North American company Douglas. Features such as engine power, wing span, fuselage length led to improvements in speed of the aircraft by a factor of two, and maximum takeoff weight and range by a factor of five since the introduction of the Douglas DC-3 aircraft in December 1935 until the rise of the Douglas DC-7 aircraft in 1956 (Frenken; Leydersdorff, 1999 [1]).

The Demoiselle was one of the first aircraft that fully satisfies the criteria for physical and conceptual precursors performs the same basic function such unassisted take-off, maneuvering and landing. Figure 1 shows the model no.20 which drawings were sent for free to Popular Mechanics magazine in 1910.

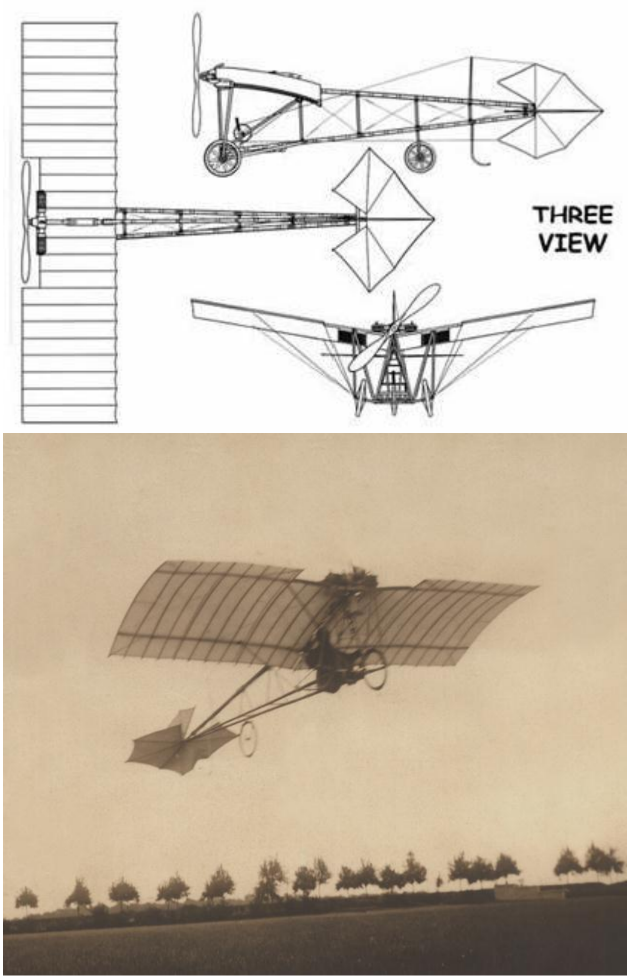

Fig. 1 Santos Dumont design No. 20 Demoiselle.

The influence of the Demoiselle on design principles of light aircraft and general aviation were studied in this work, using statistical entropy. The statistical entropy is based on the probability distribution and produces satisfactory results in studies of evolutionary phenomena at the level of any population of heterogeneous entities (Saviotti, 1988 [5]).

The methodology used for this work is that described by Frenken; Leydersdorff, 1999 [1]. The designs are organized by the first flight, or first operational flight as reference date. The main characteristics of the aircraft are stored into a database.

The parameters chosen for analysis were: wing loading, power loading, empty weight ratio and total weight, structural efficiency, structural efficiency ratio and wing loading, global configuration, construction materials and lift coefficient. This paper assesses the critical and transition rates of diffusion and convergence of the aircraft designs. The combination of these indices in the timeline sets the schedule of technological change.

2 Objective

Scaling design-level industry needs to take into account the rate of diffusion of the relationship between product characteristics. On the other hand, the coding of the design principles associated with the emergence of a dominant design involves a principle of divergence of particular design that was developed in the past.

3 Methodology

3.1 The Measurement of the Dynamic Distance Based on the Information Theory

According to Frenken; Leydersdorff, 1999 [1], the projects represent the interface between supply and demand, and since it is expressed as a function of the commitments among characteristics, the orderly arrangement is demonstrated when these commitments remain solved along the time.

The product interest characteristics are selected, it is evaluated a relationship among them and with characteristics of other products, if there is no evident variation in relationships, the project is not innovative.

Be $A_1, A_2, A_3 \dots A_n$ the airplanes in study and $C1_{A1}, C2_{A1}, C3_{A1}$ ... Cn_{A1} the characteristics of the airplane A_1 . The relationship among the A_1 characteristics may be done as follows:

$$R1_{A1} = \frac{C1_{A1}}{C2_{A1}}, \frac{C1_{A1}}{C3_{A1}} \ldots \frac{C1_{A1}}{Cn_{A1}} \quad (1)$$

$$R2_{A1} = \frac{C2_{A1}}{C1_{A1}}, \frac{C2_{A1}}{C3_{A1}} \ldots \frac{C2_{A1}}{Cn_{A1}} \quad (2)$$

$$R3_{A1} = \frac{C3_{A1}}{C1_{A1}}, \frac{C3_{A1}}{C2_{A1}} \ldots \frac{C3_{A1}}{Cn_{A1}} \quad (3)$$

$$Rn_{A1} = \frac{Cn_{A1}}{C1_{A1}}, \frac{Cn_{A1}}{C2_{A1}} \ldots \frac{Cn_{A1}}{Cn-1_{A1}} \quad (4)$$

The same procedure is done for $A_2, A_3 \ldots A_n$ and the relationship group may be considered as a likelihood distribution by dividing each relationship by the sum of all of them obtaining $DP_{A1}, DP_{A2}, DP_{A3}, \ldots DP_{An}$. Thus there is a probabilistic representation of each airplane project under study.

Based on information theory, it is possible to know the changes between subsequent projects, with the introduction of a new project in the market, calculating the distance between the representations in terms of probability distribution using the formula (Theil, 1969, 1972 [7]):

$$I(q/p) = \sum_{i=1}^{n} q1 *_{LOG2} (q1/p1) \quad (5)$$

The result of the information content of the posterior distribution $(q1.........qn)$ due to the previous distribution $(p1..........pn)$ may be considered as a theoretical distance based on the projects information in terms of relationships. Therefore, IF there are no changes in the commitments (trade-off), the likelihood distribution stays the same and in comparison with previous projects, it is verified that the project is an adapted version of them.

In that case, every qi is equal to the correspondent pi, so, I disappears, because LOG(1) = 0, otherwise, being I a positive number, indicates entropy occurrence (THEIL, 1969, 1972 [7] [8]). The I value is used as a measure of the relationship grade between two projects. Considering the analysis of two airplanes, the lower the I value, the more similar are the ratios between the airplanes characteristics, and in this case, the later project may be considered as adapted version of the previous.

3.2 The Critical Transition Measurement

The advantage of the algorithm is becomes clear when three projects examples are compared in sequential series: A - B – C.

Considering a Euclidian space, the distance between A and C is smaller than the sumo f the distance between A and B and between B and C (Pythagorean Theorem).

In contrast, the theoretical distance of the information of projects A and C indicated by $I(C/A)$ is not necessarily smaller than the sum of the distance between projects A and B, $I(B/A)$ and B and C, $I(C/B)$. In this case:

$$I(B/A) + I(C/B) < I(C/A) \quad (6)$$

The theoretical distance formula is equivalent to:

$$I(B/A) + I(C/B) - I(C/A) \quad (7)$$

And, if the inequality is confirmed, the transition from project A to project C, by project B may be considered as a *Critical Transition*.

3.3 Diffusion and Convergence

Diffusion and convergence are different phenomena. The diffusion of a particular design principle does not imply convergence, since the design can be set to different and potentially conflicting directions. For example, some companies may classify a dominant design with reference to the maximum takeoff weight, with respect to the other range or speed. If the diffusion of a design principle is observed over time, convergence can be observed as his retrospective.

The dissemination of design can be measured as the distance "*I*" in accordance with Equation 01 for all members of the population as a technology subsequently event in future time.

Diffusion here refers to the subsequent classification of a particular product design and not the diffusion of the product in terms of sales. A low value of *I* indicates a high degree of diffusion of a design. While a high value of *I* indicates a low degree of diffusion. Recalling that *I (q / p)* is a reverse indicator.

The degree of convergence is defined as the distance between all the products of a population a product above with reference to the last product of the study population. That is, a design introduced in t_n time is compared with all designs introduced during the t_1 to t_{n-1}. The average values of I indicates the degree of convergence with a low value of I indicates a high degree of convergence and a high value of I indicates a low degree of convergence.

The problem formulation is similar to diffusion except that the cumulative convergence is counted from the date of aircraft design i study to date of the first design under study, retroactively.

Although the curves in the resulting cyclic broadcast graphics and convergence are similar, the time delay values of minimum and maximum design suggests that the individual values are often very different distribution of the values of convergence. In other words, these aircraft had a strong impact in the industry are not necessarily those that converged to a given design, and vice versa, an aircraft for which converged specific design, not necessarily will spread throughout the industry. Four types of designs can be distinguished in terms of their values (low and high) diffusion and convergence:

- Designs located in the southwest quadrant with low I values of diffusion and low value of convergence are classified as "Dominant"
- Designs located in the southeast quadrant with high I values of diffusion and low value of convergence are classified as "Niche or Monopolies"
- Designs located in the northeast quadrant with high value and high I values convergence are classified as "Failures"
- Designs located in the northwest quadrant with low value and high I values convergence are classified as "Breakthroughs".

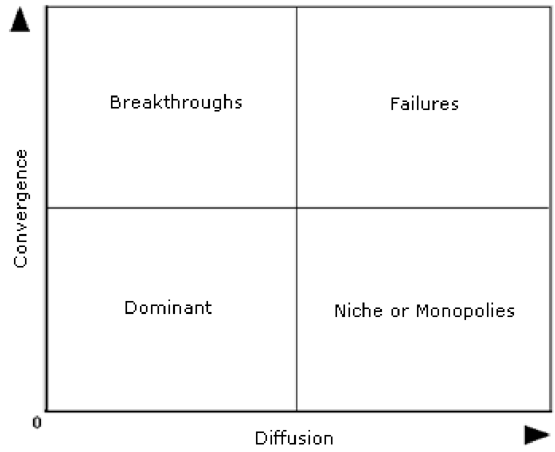

Fig. 2. Diffusion and Convergence frame

3.4 The Family Demoiselle

The Brazilian Alberto Santos-Dumont started the development of the project No 19 in order to win the Grand Prix d'Aviation established in 1907 by Ernest Archdeacon and Deutsch de la Meurthe.

The aircraft was the feeling of the event and the other distinguished by simplicity of construction and lightness. Its fuselage consisted of a single bamboo pole, tail fully mobile, high-wing screen covered with a wingspan of only 5 meters and weighed 56 kg empty and the driver his weight was 105 kg. Paragraph 19 was also the first project in the series to be called Demoiselle.

In late 1908, decided to refine the Santos Dumont Demoiselle, swapped the single spar of the fuselage by a lattice-type structure, the scale was increased to 5:55 m. The inventor started to call him No. 20. In March of 1909 makes its first flight in Saint Cyr.

On September 5 the same year, makes a test flight with the new engine Darraq 30 hp of power and new wooden propeller. The model was called No. 21.

On September 13, paragraph 21 covers nine kilometers from Saint Cyr and Buc and September 16, launches into a flying ballast of 20 kg to test the stability of the Demoiselle. Santo Dumont used this aircraft for their rides and just over 100 examples were built by the factories and Clément Bayard Dutheil &

Chambers and the project published in North American Popular Mechanics.

Finally the show ends with the model No. 22, the latest version of the Demoiselle. The model No 22 was very similar to model No. 21, differing only in the installation of Clement Bayard motor of 40 hp of power. Table 1 present the technical specifications of the models No. 19, 20, 21 and 22 used in this work.

Table 1. Demoiselle Family Technical Specifications

	D_19	*D_20*
Year	1907	1908
We [kgf]	56	110
Wo [kgf]	120	194
Bw [m]	5,0	5,5
Sw [m²].	10,20	10,20
AR	2,45	2,96
Seats	1,0	1,0
Engine	Dutheil Chamers	Antoinette
HP	18	24
Weng [kg]	27	36
V_{max} [km/h]	75	96,6
Lmax [m]	8,0	6,2
Land_gear	TD	TD
W/S [kgf/m²]	2, 411	3, 890
W/HP [kgf/HP]	14, 708	17, 795
We/Wo	0, 465	0, 567
Effestrut	0, 667	0, 438
Effestrut/W/S	0, 277	0, 112
Effestrut/W/HP	0, 045	0, 025
CL_Vmax	0, 285	0, 277

	D_21	*D_22*
Year	1909	1909
We [kgf]	110	110
Wo [kgf]	194	194
Bw [m]	5,5	5,5
Sw [m²].	10,20	10,20
AR	2,96	2,96
Seats	1,0	1,0
Engine	Dutheil Chamers	Clemént Bayard
HP	30	40
Weng [kg]	45	60
V_{max} [km/h]	96,6	96,6
Lmax [m]	6,2	6,2
Land_gear	TD	TD
W/S [kgf/m²]	3, 890	3, 890
W/HP [kgf/HP]	14, 236	10, 677
We/Wo	0, 567	0, 567
Effestrut	0, 356	0, 219
Effestrut/W/S	0, 091	0, 056
Effestrut/W/HP	0, 025	0, 021
CL_Vmax	0, 277	0, 277

Where:
TD = Tail Drag
We = Empty Weight
Wo = Total Weight
Bw = Span Wing
Sw = Wing Area
AR = Aspect Ratio
Weng = Engine Weight
Vmax = Maximum Speed
Lmax = Maximum Length
W/S = Wing Load
Effestrut = Structural Efficiency

3.5 The Database

The Brazilian Santos Dumont and the Wright brothers stand out as pioneers of aviation and the dispute over who was first up still occurs today. Many have tried flying, some given up , and some failed, others have not had the chance to try it again and others remained anonymous.

When making the database for this study were surveyed several designs done prior to the Santos Dumont and the Wright brothers however, very little or no information about the technical characteristics of those aircraft were obtained. Precursors as John Strinfellow, Jean-Marie Le Bris, Hiram Maxim, Philips and New Zealander Richard Pearse etc. It is claimed Pearse flew and landed an interesting machine heavier than air moved in March 31, 1903, about nine months before the Wright brothers flew their aircraft and whose replica built by Ivan Mudrovcich awaiting authorization to be tested this year in New Zealand.

The record in the database begins in 1907 with the aircraft followed by 19 Demoiselle Farman III, Flyer III, etc. Demoiselle 20. After the year 1903 and until today, the aircraft category for the proposed study and its technical characteristics are readily available in many bibliographic references.

For this work order excluding aircraft designed during the first and second world war.

3.6 Variables in Study

The selected design parameters for case study are:

Wing Loading (W_o/S_w)

$W_o = Total\ Take - off\ weight$
$S_w = Wing\ area$

Weight-Power Ratio (W_o/Hp)
$Hp = Motor\ power$

Structural Efficiency

$$EE_{est} = \frac{W_o - W_{empty} - W_{motor}}{W_{empty}}$$

$W_{empty} = Airplane\ empty\ weight$
$W_{motor} = Airplane\ motor\ weight$

Structural Efficiency and Wing Loading
$EE_{est}/\ (W_o/S_w)$

Structural Efficiency and Weight-Power Ratio
$EE_{est}/\ (W_o/Hp)$

Configuration – The adopted values are:

- 1(one) for monoplane
- 2 (two) for biplane
- 3 (three) for biplane/*canard*

The wing configuration parameter is related to the relative position and the number of wings, monoplane or biplane, and the relative position to the empennage (conventional or canard).

Fuselage Length by Total Weight
$L_{fus}/\ W_o$

Lift Coefficient at Maximum Speed

$$CL_{vmax} = \frac{W_o}{qS_w}$$

$$q = Dynamic\ Pressure = \frac{\rho V_{max}{}^2}{2}$$

3.7 Considerations

Regarding to data not provided or unavailable, the following considerations were made:

a) The empty weight of the aircraft Flyer III, owned by the Wright brothers was calculated by subtracting the weight of Orville Wright as pilot, the total weight of the aircraft.

b) The motors weight, that is not found, was calculated as follows:
-For engines built between 1907 and 1928 the value of the weight of the motor is obtained as the value of its horsepower multiplied by 2 kg;
-The maximum speed for pioneer aircrafts in the period between 1907 and 1909 was considered as the measured speed the time of flight.

c) About the selection of aircraft for study, limits have been set up for wing loading of 70 kgf/m² and minimum power load of 4 kgf / Hp.

4 Results

4.1 Diffusion

By the Fig. 3, it is possible to see that the Demoiselle Family has the smallest *I* values in the early's of aviation, meaning higher diffusion.

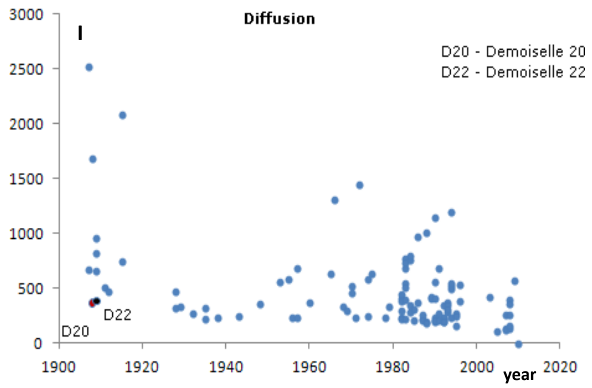

Fig. 3. Diffusion Results

4.2 Convergence

The Demoiselle Airplanes Family has higher convergence values compared to the airplanes designed and built in the early's of aviation (Fig. 4). This result means that the Demoiselle Family is not based in principles of previous airplanes.

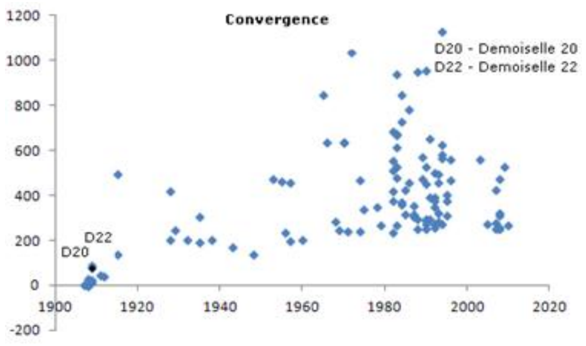

Fig. 4. Convergence Results

4.3 Diffusion and Convergence

By analyzing Fig.5, it is possible to infer that the Demoiselle Family were dominant and conducted the design principles of the category in study.

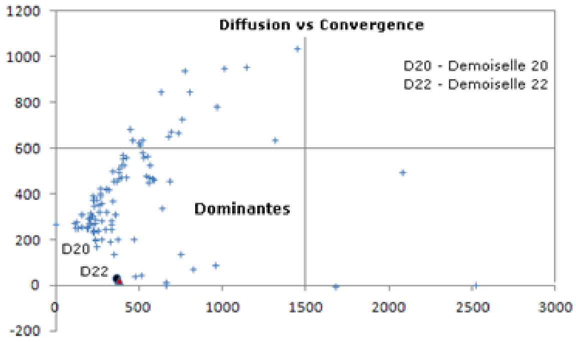

Fig. 5. Diffusion and Convergence Results

5 Conclusions

Among the Demoiselle aircraft family, the designs number 20 and 22 may be considered dominant and influenced the design principles of light aircraft and general aviation, it is a link in an unbroken chain that leads to the modern airplane through incremental.

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