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REQUIREMENTS AND TRENDS IN FUEL CONSUMPTION IN TRANSPORT MISSION WITH AIRCRAFT AND SURFACE VEHICLES

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Abstract

The A. recommended the adoption of non-dimensional factor f called "energy utilization factor" which relates the vehicles's net transport capability in the mission taken into consideration, i. e. the payload product expressed in weight by route distance, to the equivalent mechanical energy used.

The A. produced the f values worked out from a few hundred sea, land and air vehicles of 15 different types in connection with the principal missions which they normally carry out and show that the turbine propeller engine aircraft and, to an even greater degree, the turbojet aircraft are the only type of vehicles offering higher transport speeds without a corresponding reduction in the energy utilization factor.

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If the relative position of the most widely diversified types of transport vehicles is to be assessed straight out, in terms of the amount of fuel used in corresponding transport missions, one has to refer to a generally valid parameter.

To this effect, the energy used, irrespective of type must be expressed in one single form, e. g. the equivalent mechanical energy and the payload, either freight or passengers must be measured in terms of weight.

To this effect, ever since 1972, we recommended the adoption of a non-dimensional factor f called "energy utilization factor" which relates the vehicle's net transport capacity in the mission taken into consideration, i.e. the payload product expressed in weight by route distance, to the equivalent mechanical energy used (1)

This factor in a more general case applies to electrical vehicles as well as to those moved by muscle power.

Generally speaking, with any vehicle in variable motion the instant factor of energy utilization can be defined as the ratio

$$f_i = \frac{Q_p V_i}{P_m} \qquad [0]$$

where

Q_p stands for the payload in the instant "t" $[Kg]$

V_i stands for vehicle's instant speed $\left[\frac{m}{s}\right]$

P_m stands for mechanical power corresponding to the hourly energy consumption at the instant "t" $\left[\frac{Kgm}{s}\right]$

The factor relating to a mission taking place over a given route at the time $(0, T)$ is given by (see Fig. 1)

$$f = \frac{\int_0^T Q_p V_i \, dt}{\int_0^T P_m \, dt}$$

If Q_p = constant it follows that

$$f = \frac{Q_p \int_0^T V_i \, dt}{\int_0^T P_m \, dt} = \frac{Q_p L}{E_m}$$

in which L is the actual route distance $[m]$

$E_m = \int_0^T P_m \, dt$ is the energy, in mechanical units, equivalent to that used by the vehicles on a given mission $[Kgm]$

In the case of aircraft and ships, the factor f is made to refer to the distance D between the utmost points of each single section of the route considered

$$f = \frac{Q_p D}{E_m} \qquad [0]$$

The factor "f_u" can be explained as the ratio between net transport capacity and the energy used in the mission, expressed in mechanical units - or as the net transport capability corresponding to each unit of the equivalent mechanical energy by the vehicle in the mission taken into consideration.

In a paper published in the Acts of the 1973 Annual Conference of the International Institute of Communications of Genoa, the Author, in co-operation with G. Gonella, (2) produced the of values worked out from a few hundreds sea, land and air vehicles of 15 different types in connection with the principal missions wich they normally carry out.

A summary diagram of these results is shown in Fig. 2, in which V_{mm} is the speed of the mission.

By drawing a straight line tangent to the tanker and propeller aircraft areas it may be observed that, with the exception of electric trains and propeller turbine engine and turbojet aircraft the points relating to the other vehicle types fall below the foregoing straight line.

Propeller turbine engine aircraft and, toa greater degree, turbojets cover separate areas to the right of the diagram, and their speed fields are quite higher than those of propeller aircraft, even though their f values fall roughly within the same area covered by the latter.

Lastly, the supersonic passenger transport aircraft in regular service (on the North Atlantic route ($V_{mm} \sim 2000\ km/h$; $f = 0{,}36$) the Concorde, is shown in isolation in the right hand side of the diagram.

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The increase in speed from the propeller engine to the turbine propeller engine is the result of the aircraft's lower drag, owing mainly to a better integration of power unit into the air frameand its smaller dimensions and, as far as jet aircraft are concerned, to the improved engine performance in high flight altitude, i.e. in rarefied air.

With regards to the f value, there is no observable reduction; on the contrary, an increase can be detected, in spite of higher transport speeds. This because the shift from propeller engines to turbine propeller engines, to jet turbine engines meant a considerable reduction in power unit weight (per unit of output), in addition to the fact that the increase in speed was not achieved by raising the installed power compared to the weight (specific horsepower at take-off) (Fig. 3).

The weight of power unit which account for 20% of the overall propeller aircraft weight at take-off, is only 10% in case of turbojets, and tends to shrink to 5%. (3)

This lower power unit weight makes possible a corresponding increase in the payload, hence of the f factor, in spite of the increase in speed, contrary to what is the case, as we have seen, with surface vehicles.

The turbine propeller engine aircraft and, to an even greater degree, the turbojet aircraft are the only vehicles offering higher transport speeds without a corresponding reduction in the energy utilization factor.

This remontable behaviour on the part of aircraft can be mainly explained by the fact that aircraft, like all air machines, are the only ones wich in carrying out their transport missions, can rely on a third dimension - altitude - which enables them to take advantage of an environment with lower drag characteristics.

In addition to this, aircraft evolution has alone benfited directly and to a considerable degree from the most advanced, complex and costly technologies, themselves the outcome of refined R & D programmes (for military reasons, mostly implemented in the United States), and from the fact that aircraft are characterised by a high level of productivity.

The evolution of all land and sea machines is moving in the same direction, even though the tempo is slower and account must be taken of costs which can be afforded, and yet use is often made of aeronautical technology advancements in the fields of materials and power units, and of improvements in shapes for the reduction of drag in general.

References

(1) - G. Gabrielli - Considerazioni sul grado di utilizzazione dell'energia richiesta nei veicoli per passeggeri e merci di tutti i tipi in rapporto alla loro "capacità netta di trasporto" (XX Convegno Internazionale delle Comunicazioni, Genova 8-13 ottobre 1972).

(2) - G. Gabrielli e G. Gonella - Sul valore del "fattore di utilizzazione dell'energia" di alcuni tipi di veicoli da trasporto alla velocità media delle rispettive "missioni basiche" (XXI Convegno Internazionale delle Comunicazioni, Genova 8-13 ottobre 1973).

(3) - G. Gabrielli - Sulla valutazione del peso degli impianti motopropulsori dei velivoli da trasporto (Atti dell'Accademia delle Scienze di Torino, 1977).

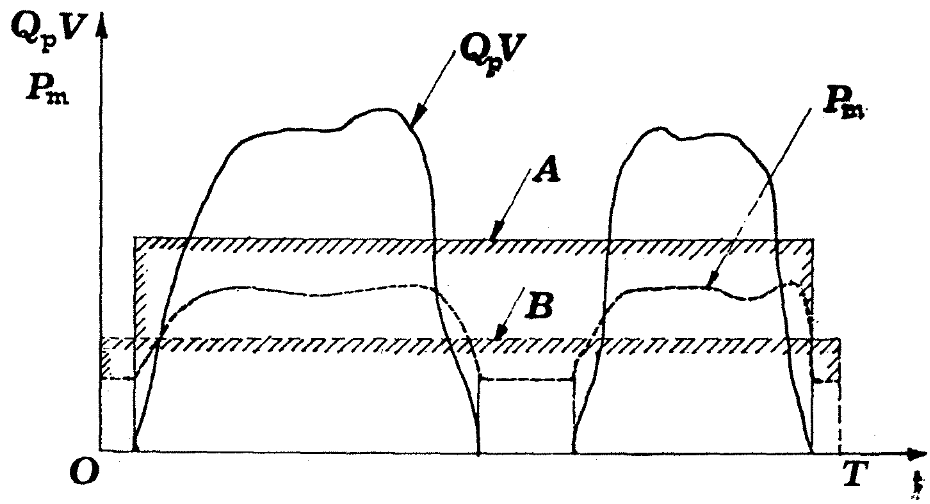


FIG. 1

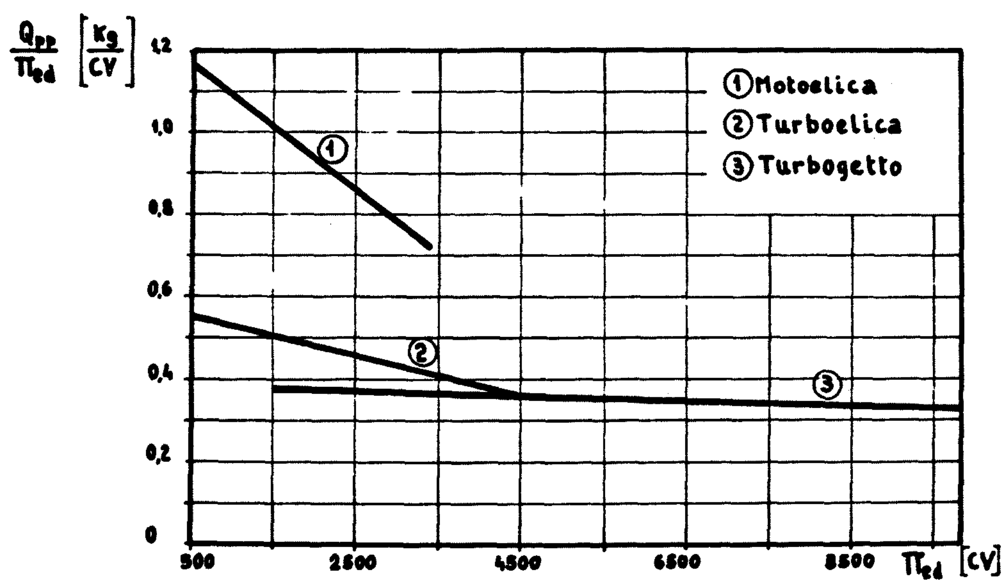
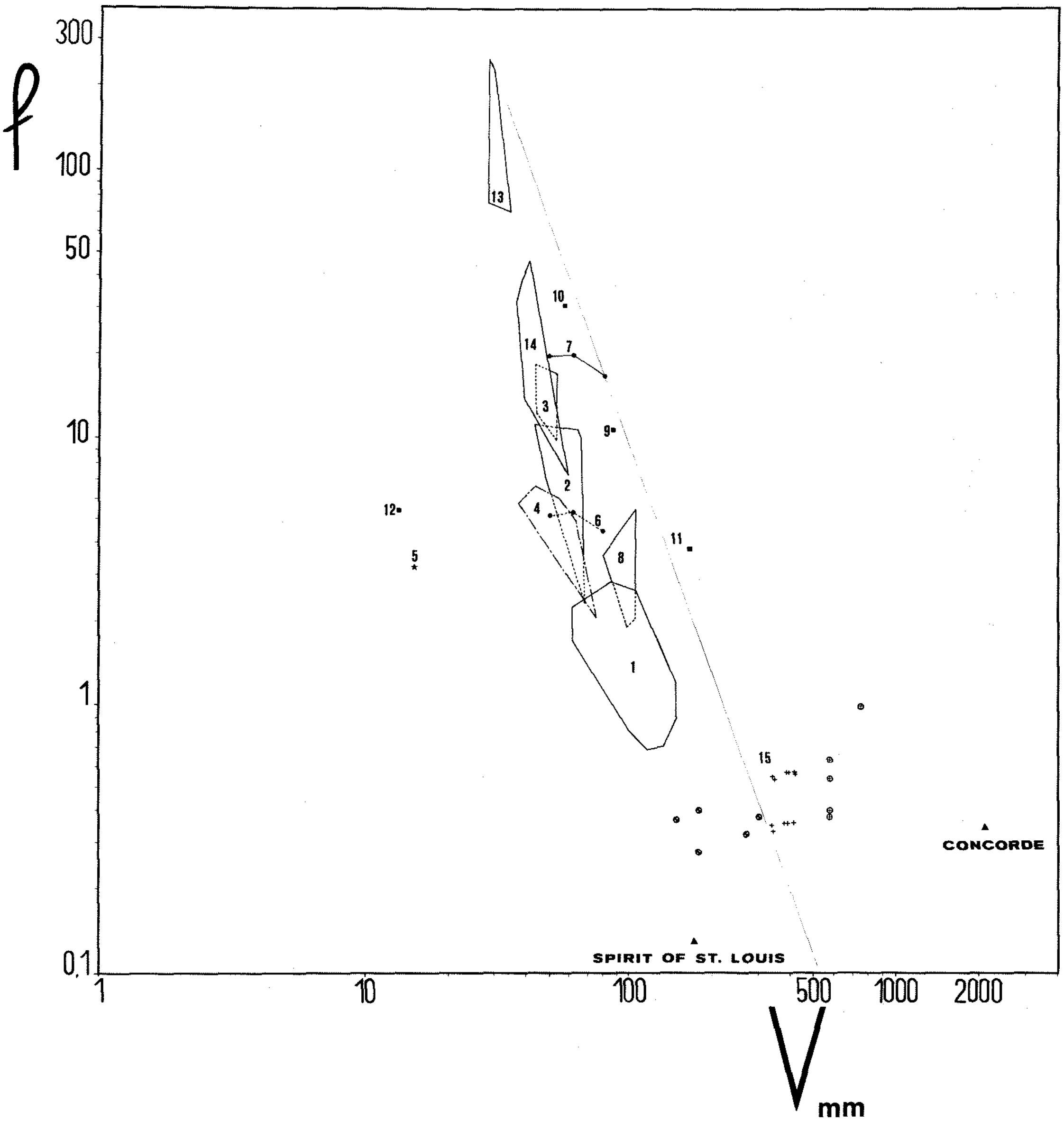


Fig. 3 -Peso specifico degli impianti motore



1 - Automobili
2 - Autocarri
3 - Autocarri con rimorchio e autoarticolati
4 - Autobus urbani e interurbani
5 - Autobus dell'A.T.M. di Torino
6 - Treni diesel-elettrici passeggeri
7 - Treni diesel-elettrici merci
8 - Automotrici diesel con e senza rimorchio
9 - Treni elettrici passeggeri
10 - Treni elettrici merci
11 - Elettrotreni

12 - Tram dell'A.T.M. di Torino
13 - Navi cisterna e mineraliere
14 - Navi portacontainers
15 - Aeroplani passeggeri e merci di grande e medio tonnellaggio
a motoelica
+ a turboelica
⊕ a turbogetto

FIG. 2