by Fe^{2+} interstitial for charge compensation; (v) three Fe^{2+} substitutional accompanied by two Fe^{3+} interstitial for charge compensation. The second case is the least probable because of the partially covalent (about 50 percent) nature of the Si-O bond in the three-dimensional quartz network. Whether Fe^{2+} is substitutional or interstitial remains to be determined.

Thus, while substitutional Fe^{3+} in positive rhombohedral growth is chemically reduced by ionizing radiation and while interstitial Fe^{3+} in basal growth is insensitive and remains essentially unchanged, Fe^{3+} ions produced by heating of Fe^{2+}-doped quartz are further enhanced, rather than reduced, by x-irradiation in some manner not understood. One can conclude that there is a coordination position specificity for sensitivity of the Fe^{3+} ion to ionizing radiation in quartz and that the effect of ionizing radiation depends on whether Fe^{3+} was introduced during growth of the quartz or by oxidation of Fe^{2+} after growth of the quartz. Thus, in quartz the role of Fe^{3+} related to radiation effects is not a simple one, and a complete understanding of the solar wind and of solar radiation effects on the silicate minerals and glasses of the lunar samples may be difficult where, in addition to iron, "smaller amounts of manganese and titanium present may also be important in these reactions" (*4*).

ALVIN J. COHEN
FARKHONDA HASSAN

Department of Earth and Planetary Sciences, University of Pittsburgh, Pittsburgh, Pennsylvania 15213

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Insect Flight: Lift and Rate of Change of Incidence

Abstract. *Large changes in lift output result when a simulated insect wing, undergoing a downstroke, is subjected to a dynamic change of incidence. Given a large positive rate of change of incidence, transient lift values several times those realized in steady-state operation at the same angle of incidence are obtained. Thus a means exists by which insects achieve several times the lift expected by conventional quasi-steady considerations.*

The fluid mechanics of lifting surfaces becomes less certain as the surface (i) becomes heavily loaded, (ii) experiences a motion with a large unsteady component, or (iii) moves at a scale neither decidedly viscous nor inviscid. The domain of insect flight embraces all these areas of difficulty. Consequently the bromide concerning the prevalence of "bumble bee" aerodynamics over the pretensions of engineers contains a grain of truth. Performance analyses of several species of beetles (*1*) and *Drosophila* (*2*) reveal a force decrement factor of roughly two or three, that is, the forces necessary for sustenance appear several times larger than those estimated as available, where judgments of force available are based on general steady-state low Re (Reynolds number, or the ratio of inertial to viscous forces) experiments (*3*) or steady tests of a detached wing (*2*). Experiments with a simulated cockchafer, *Melolontha vulgaris* (*4*), indicated a satisfactory agreement between measured lift and insect weight. Whereas the lift was shown to be circulatory in origin and dependent on the degree of unsteady flow, no attempt was made to identify the source of the large requisite force coefficients.

My study concerns influence on lift of a simulated *M. vulgaris* wing. Particular emphasis is placed on those factors capable of producing larger sustaining forces than those revealed in quasi-steady or steady-state analyses. Specifically, the results of wing incidence, rate of change of incidence, and rate of change of downstroke velocity are presented to identify the mechanism by which lift is produced.

The apparatus (Fig. 1) consisted of an articulated single wing mounted so as to flap harmonically through a stroke of 108°. Geared to the flapping drive, a separate cam controlled incidence. A groove machined into the incidence cam moved a follower arm about its pivot, shifting a bobbin along the main square driveshaft. A nylon cord, tied at one location on the bobbin and passing through holes in its opposite side, formed an endless loop that drove the incidence sheave through friction. The latter was directly connected to the wing root. Thus any desired incidence or rate of change of incidence was obtained by cutting an appropriate groove in the incidence cam. As the incidence control arrangement necessarily suffered (i) lost motion due to clearances between components, and (ii) deflection due to operating loads, true values of incidence and rate of change were measured under full load through use of a Strobotac and sighting device.

Mounted in a miniature open-throat wind tunnel, the flapping plane was displaced 60° from the horizontal plane of the tunnel, roughly duplicating the stroke-plane inclination for a forward-flying *M. vulgaris*. Lift values were obtained by measuring the change of momentum of the airstream as it crossed the stroke plane of the beating wing. In this quasi-steady treatment, variations in momentum are averaged over a cycle. Instantaneous values are inappropriate, not only for certain fundamental reasons (*5*), but also because virtual-mass force exists on the instantaneous level. Net virtual-mass force may be shown to be zero over an entire cycle (*6*) even for large-order perturbations. Thus, the use of mean values automatically eliminates all influence of virtual mass.

The expression utilized for generated lift was: lift equals the mass flow through the flapping plane times the downward component of air velocity, specifically, that component normal to the flight path or the wind-tunnel axis. As time-averaged values from a single point in space (0.7 wing radius, mid-downstroke azimuth) were employed, the resulting lift figures reflect the situation during downstroke at a location where lift is near maximum.

In practice, the sensor of a commercial hot-wire anemometer was positioned on the upwind and downwind sides of the flapping plane to obtain the local induced-velocity data. Calibration was obtained with a whirling arm arrrangement. Triggered at the start of downstroke, the hot-wire trace was

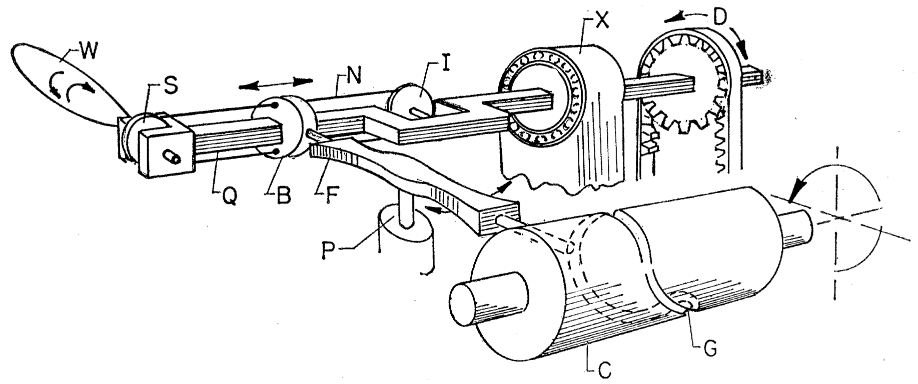

Fig. 1. Apparatus schematic. Mechanism to control incidence of simulated *Melolontha vulgaris*. Not to scale. *W*, Wing; *S*, incidence sheave; *N*, nylon cord; *B*, bobbin; *C*, incidence cam; *G*, groove; *F*, follower arm; *P*, pivot; *I*, idler; *D*, flapping drive; *X*, bearing support; *Q*, square shaft.

displayed on a conventional oscilloscope screen and photographed.

The sensors will indicate the maximum instantaneous velocity when it is perpendicular to the direction of flow. Therefore the sensor was positioned and data taken at 10-deg increments throughout 180 deg, thus permitting the determination of instantaneous velocity by a search of all records at a given elapsed time from the start of downstroke. That sensor record displaying the largest instantaneous velocity at each established increment of time indicated both the appropriate velocity and the angular direction of flow. Mean velocity-vector values for the complete cycle were obtained graphically from constructions of moment-by-moment velocity-vector diagrams over the cycle.

The incidence angle (Fig. 2A) is defined as that angle between the airfoil chordline and the local airstream velocity, without corrections for downwash, instantaneously achieved as the wing moved through the test zone. In all cases shown, the instantaneous downstroke velocity (654 cm/sec) and forward velocity (260 cm/sec) were identical. Thus, for a given angle of incidence, the curves represent the wing arriving at the test zone with different velocity and attitude histories, or both, to share an identical present, on its way to different futures.

The lift generated through a large increasing angle of incidence (10,600 deg/sec) was generally greatest; when compared to a similar but negative rate of change of incidence (− 16,000 deg/sec), the superiority of the positive rate change in terms of lift is pronounced at all angles of incidence. At all angles of incidence, the negative rate offers little lift, and that lift is frequently associated with a severe stall. No stall was produced by the positive incidence change. The small positive incidence rate (266 deg/sec) lift values fall between those generated by the larger positive and negative incidence rates. Propeller operation, similar to the small positive in terms of incidence rate (412 deg/sec), differed principally in having a constant tangential velocity for each wing element with respect to time instead of a simple harmonic tangential velocity. Propeller lift was generally similar to that developed in the small positive rate condition, except that the lift was smaller at large angles of incidence, where stall effects become significant. When lift is plotted against rate of change of incidence (not given) the lift values at a large rate of change are several times those realized at true steady-state conditions in the 15- to 35-deg incidence range.

Figure 2A also contains a replication obtained in the large, increasing angle-of-incidence mode. Performed to supply a sense of experimental error,

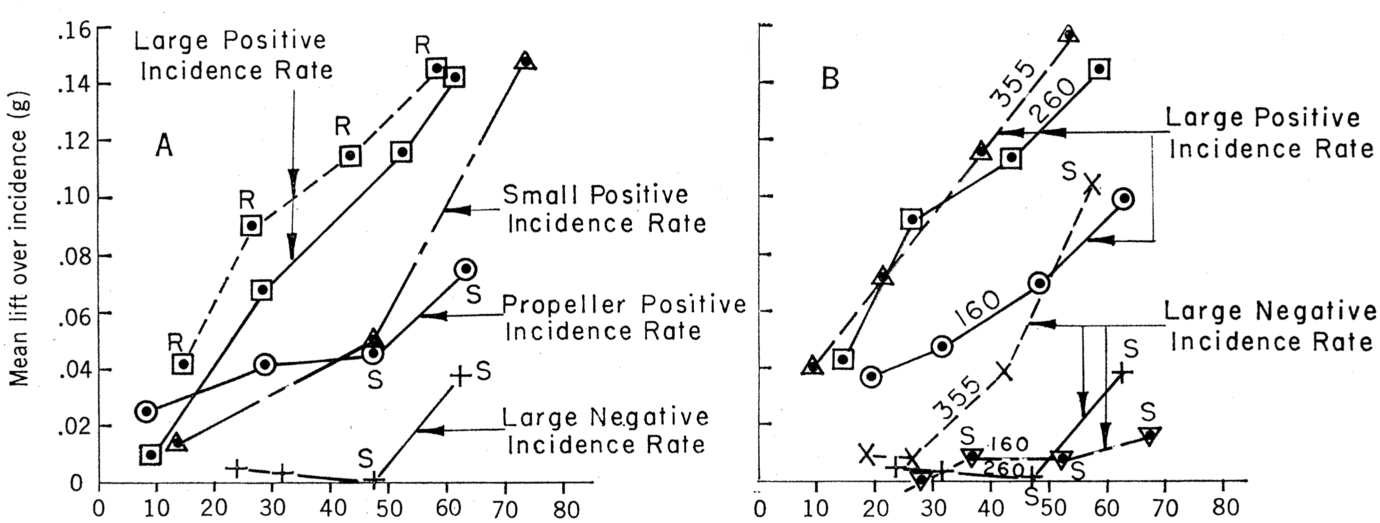

Fig. 2. (A) Variation of mean lift developed in a single downstroke, at a fixed point in space, with incidence and incidence rate of change. Large positive incidence rate equal to + 10,600 deg/sec. Small positive incidence rate equal to + 266 deg/sec. Propeller increasing rate of incidence equal to + 412 deg/sec. Large negative incidence rate equal to − 16,000 deg/sec. Forward velocity 260 cm/sec. Replication points flagged with *R*; severe stall with *S*. Abscissa represents instantaneous angle of incidence at measurement station (0.7 wing radius, mid-downstroke azimuth). (B) Variation of mean lift developed in a single downstroke, at a fixed point in space, with forward velocity and incidence at two incidence rates. Large positive incidence rate equal to + 10,600 deg/sec. Large negative incidence rate equal to − 16,000 deg/sec. Forward velocities (centimeters per second) indicated on each curve.

the replication involved a newly manufactured wing, a different hot-wire sensor operating on a separate calibration curve, and a drive system rebuilt to offset wear. While the replication differed sufficiently from the original to suggest that any consideration of minor trends in the data is unrealistic, the major trend was preserved.

The influence on lift of the rate of incidence change is given (Fig. 2B) at various forward velocities. In all cases the large increasing incidence rate was 10,600 deg/sec, the decreasing rate −16,000 deg/sec, the instantaneous downstroke velocity 654 cm/sec, and the flapping mode one of simple harmonic motion. The large positive incidence rate effected a greater lift, as compared to the large negative rate, at all forward velocities tested. The decreasing incidence rate was associated with reduced lift, severe stalling, or both.

Two things may explain the effect of rapid changes of incidence. First, is the Magnus effect, wherein a rotating surface produces a circulation which, in combination with a velocity of translation, yields lift. The dynamic incidence change may be viewed as a form of rotation within this analogy; a positive rate of change corresponds to an increase of circulation and a negative rate corresponds to a decrease. An analysis of this matter (*6*) in the case of an oscillating wing subjected to large perturbations indicates qualitative agreement between the experimental results (rate of change of incidence versus lift) and predicted performance. A second rationale is based on viscous effects, in particular, destalling attendant upon certain unsteady motions. An impulsive change of incidence given to an airfoil on the verge of stalling will, if positive, delay stall until a larger angle of incidence and more lift is developed than are manifest in a steady state (*7*). Conversely, a negative incidence impulse delivered near stall will create an exaggerated stall effect, compared to steady-state values. As many of the experimental results were gathered at large angles of incidence, suggestive of the stall domain, it is possible that the influence of impulsive incidence on stall is significant with respect to the lift generated. The relative significance of these two factors in causing high lift is uncertain. Both are probably active; however, the violent stalls produced by a negative incidence rate and the low lift at small angles of incidence, regardless of incidence rate, suggest that viscous effects are dominant.

In view of the large rate of change of incidence values employed in these experiments, it is useful to examine flight values. Of the insects whose flight characteristics have been evaluated to the necessary degree of accuracy, the desert locust *Schistocera gregaria* (*8*) displays a small rate of incidence change in downstroke. The diptera studied by Nachtigall (*9*) experienced a linearized rate of incidence change at mid-downstroke of roughly 20,000 deg/sec. The latter value is compatible with my largest values from simulated tests. The paucity of available measurements in vivo precludes any general statement concerning augmentation of lift by insects through rapid changes of incidence. However, it may be that at least some insects do this.

Insect flight has been treated as reducible to a quasi-steady approximation, wherein the wing takes on instantaneous lift values corresponding to steady-state values at equivalent velocities and attitudes. Such an assumption is unwarranted where the angle of incidence changes rapidly. Through use of large positive rates of change of incidence at mid-downstroke, insects may develop lift values several times those apparent in quasi-steady models. I suggest that the apparent gap between requisite and available force coefficients for certain insects may reflect the quasi-steady analysis by investigators and the employment of an incidence change strategy by the insects.

LEON BENNETT

School of Engineering and Science, New York University, 401 West 205 Street, New York 10034

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Absorption of Proteins and Peptides in the Far Ultraviolet

Abstract. *An absorption peak for the peptide bond at 187 nanometers has been confirmed; a protein assay at this wavelength allows quantitation of proteins in aqueous solution at concentrations between 0.1 and 25 micrograms per milliliter. Assays are conducted at 6°C to take advantage of the reduction of end-absorption of water with temperature.*

Methods for protein assay are complicated by the contribution of aromatic side chains to the final colorimetric or spectrophotometric determination (*1*). Since the content of such side chains varies considerably from protein to protein, it is necessary to construct a separate standard curve for each species of protein; furthermore, when mixtures of proteins are to be assayed the contribution of each may be difficult to judge. This situation holds true for both colorimetric assays such as the Lowry method (*2*) and spectrophotometric assay at 280 nm (*1*). Because of this there have been several attempts to develop an assay based on the ultraviolet absorption of the peptide bond which would be relatively free of side chain contribution and would yield a true measure of the protein content.

Although an absorption peak for the peptide bond has been described at about 186 nm (*3, 4*), there have been severe limitations on the capacity of conventional spectrophotometers to operate in this range. Apart from optical limitations of the ultraviolet range, the absorption of oxygen below 200 nm has required nitrogen purging of the light path. In addition, the end absorption of water and salt solutions in the far ultraviolet is so large that stray light becomes a limiting factor. The contribution of stray light leads to spurious absorption peaks (*5*) and is further complicated by the need to stabilize most protein solutions by the