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Highlights

- Electric Integral Modul Aircrft
- Experimental Ablation Measurements
- Peculiarities of UAV Construction
- Graduates of Ukrainian Universities

Discovering Thoughts, Inventing Future

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By Daniel Odion Iyinomen

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Experimental Ablation Measurements in Hypersonic Flows using Novel Preheating Technology

Daniel Odion Iyinomen

Abstract- Measurements of mass ablation rates in hypersonic flows are used to calibrate computational models, and the arc jets have been the norm for ablation experiments. However, the quality of experimental data from arc jet facilities are limited by non-uniform enthalpy distribution, non-equilibrium state, change of surface quality during testing, and the extent of oxidation. This publication presents an innovative research work, leading to a new era of scientific breakthrough in aerothermodynamics experiments and hypersonic re-entry studies using new preheating technology. The impetus for this new technology is to help reduce the large variations in ablation rate predictions around the world. A graphite disc of 50 mm diameter and 2 mm thickness was heated from the downstream side with a plasma to approximately 2500 K, and then exposed to a cold Mach 4.5 flow using the Ludwieg tube facility at the University of Southern Queensland (TUSQ) in the atmospheric blowdown configuration. The experimental probe was very similar to the European standard probe, and presented herein are the results from material loss and surface recession for the experiments. The next generation experimental model (NGEM), which has been specifically designed for the next generation of researchers is also presented, to be used in validating computational models in excess of 3000K surface temperatures under conditions that replicate characteristics of re-entry flights.

I. Introduction

The dominance of aerodynamic heating in hypersonic flight regime [Tranet al. 2006] is the most critical factor that drives the principal design characteristics of any re-entry vehicle [Goulard 1958]. Methodologies for aerodynamic heat estimations range from simple to complex, depending on the required amount of time and computational resources [Poovathingalet al. 2016]. The maximum heat flux for a blunt-body can be assumed to occur at the stagnation point [Duffa2013], though there are some few exceptional cases. Fay and Riddle originally investigated stagnation point heating problem in the 1950s [Fay and Riddell 1958], then further investigated for re-entry applications by Allen and Eggers [Julian and Eggers 1958], and by Sutton and Graves during the Apollo era for different gas mixtures [Sutton and Graves 1971]. A very simplified expression for estimating the hypersonic aerodynamic heating was proposed by Sutton and Graves as stated in Eq. (1).

$$Q_{Conv} = 1.73 \times 10^{-4} \left[\frac{\rho_\infty}{R_n}\right]^{0.5} V_\infty^3 \qquad \text{Eq. (1)}$$

where, Q_{Conv} is convective heat flux (W/m2), ρ_∞ is free stream density (kg/m3), R_n is nose radius of body (m), V_∞ is free stream velocity (m/s). A similar relation for a preliminary analysis of the stagnation point heat transfer was also proposed by Detra and Hidalgo [Detra and Hidalgo 1961] as stated in Eq. (2).

$$Q_{Conv} = 5.16 \times 10^{-5} \left[\frac{\rho_\infty}{R_n}\right]^{0.5} V_\infty^{3.15} \qquad \text{Eq. (2)}$$

Some mathematical modifications were later proposed by Tuber (1989) by addressing the enthalpy at the edge of boundary layer (h_w) and total enthalpy at the stagnation point (h_o) [Tauber 1989] as stated in Eq. (3).

$$Q_{Conv} = 1.83 \times 10^{-4} \left[\frac{\rho_\infty}{R_n}\right]^{0.5} V_\infty^3 \left[1 - \frac{h_w}{h_o}\right] \qquad \text{Eq. (3)}$$

The above-mentioned equations explain why windward-facing surface of a re-entry vehicle is always kept blunt because the heating varies directly with the cube of velocity and inversely with the square root of the nose radius [Chhunchha 2018]. However, these empirical formulations were reasonable approximations that do not characterize the exact solution. Goulard reported that the validity of Lees, Fay and Ridell heat transfer solutions are shown to correspond to the limiting case of an infinitely fast catalyst; and extended the solutions to the general case of a wall offinite catalytic efficiency, by introducing a correction factor [Goulard1958]. The more exact numerical results of Fay and Riddell, are correlated as (1) equilibrium boundary layer, (2) frozen boundary layer with an equilibrium catalytic wall, and (3) frozen boundary layer with a noncatalytic wall [Anderson 2000]. For equilibrium boundary layer (spherical nose), the surface heat transfer (Q_w) is given as Eq. (4).

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$$Q_w = 0.76Pr^{-0.6}[\rho_e\mu_e]^{0.4}[\rho_w\mu_w]^{0.1}\sqrt{\left(\frac{du_e}{dx}\right)_s}\left(h_{0_e} - h_w\right) \times \left[1 + \left(Le^{0.52} - 1\right)\left(\frac{h_D}{h_{0_e}}\right)\right] \quad \text{Eq. (4)}$$

where ρ is the mass density, μ is the absolute viscosity, $\frac{du_e}{dx}$ is the velocity gradient, h is the enthalpy per unit mass, Pr is the Prandtl number and the subscripts *0*, *e* and *w* describe the total, the conditions at the edge of the boundary layer edge and at the wall, respectively. Le is the Lewis number, h_D is the dissociation enthalpy which is expressed as the product of the enthalpy of formation $\Delta h^0_{F,i}$ of species i and its mass fraction y_i stated in Eq. (5).

$$h_D = \sum_{i=1}^{N} y_i \Delta h^0_{F,i} \quad \text{Eq. (5)}$$

For frozen boundary layer with an equilibrium catalytic wall (spherical nose) the surface heat transfer (Q_w) is stated in Eq. (6).

$$Q_w = 0.76Pr^{-0.6}[\rho_e\mu_e]^{0.4}[\rho_w\mu_w]^{0.1}\sqrt{\left(\frac{du_e}{dx}\right)_s}\left(h_{0_e} - h_w\right) \times \left[1 + \left(Le^{0.63} - 1\right)\left(\frac{h_D}{h_{0_e}}\right)\right] \quad \text{Eq. (6)}$$

For frozen boundary layer with a noncatalytic wall (spherical nose), the surface heat transfer (Q_w) is stated in Eq. (7). It is generally believed that for frozen flow profile, the atomic mass fraction between the wall and the outer edge is not as a result of any chemical reactions within the boundary layer, but rather is completely as a result of diffusion of the atoms from the outer edge to the wall [Anderson 2000].

$$Q_w = 0.76Pr^{-0.6}[\rho_e\mu_e]^{0.4}[\rho_w\mu_w]^{0.1}\sqrt{\left(\frac{du_e}{dx}\right)_s} \times \left[1 - \left(\frac{h_D}{h_{0_e}}\right)\right] \quad \text{Eq. (7)}$$

The velocity gradient $\frac{du_e}{dx}$ can be represented by β, the total enthalpy h_0 and the chemical compositionat the boundary layer edge contained in the h_{D_e} term, including the wall conditions of enthalpy and catalycity can then be treated as duplication parameters [Sakrakeret al. 2021]. The exponent of Lewis number, *Le*, in Eq. (4) is given as 0.52 for an equilibrium boundary layer and 0.63 for a frozen boundary layer with fully catalytic wall; wherein the latter is suggested as 2/3 by Lees [Lees 1956]. Due to the crucial nature of stagnation heating and the boundary layer chemistry in hypersonic entries, it is very important to reproduce the flight conditions in ground test facilities as accurately as possible. Figure 1 presents the summary of recombination rate parameter for various wall conditions.

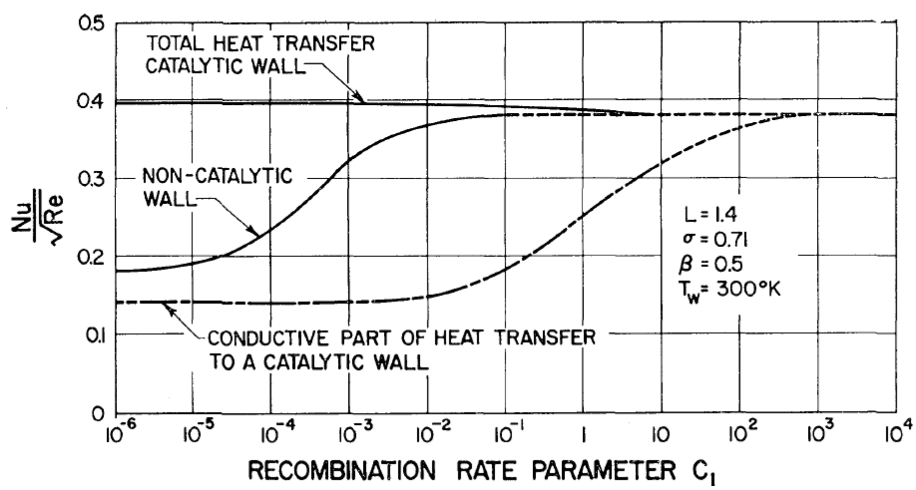

Figure 1: Summary of recombination rate parameter for various wall conditions [Fay and Riddell 1958].

In high-enthalpy facilities, the gas is either partially or totally dissociated before reaching the surface. Using such facilities for Martian re-entry studies, carbon dioxide molecules do not get to the surface because they start to dissociate inside the arc chamber, thus, having some consequences on the nozzle flow and quality of experimental data. In addition, the use of a gas different from air, such as a CO_2 environment, has a strong impact on the arc chamber and notably on the arc performance in most high-enthalpy facilities [Bugel et at 2011]. In the present work, these high-enthalpy problems are completely eliminated and the surface temperature is completely responsible for the actual dissociation and recombination of gas species. The rationale behind this innovation is to achieve an alternative thermal coupling of gas–surface interactions with a high degree of confidence [Iyinomen 2022a]. The credibility demonstrated for extreme re-entry problems makes the present work an indispensable tool for re-entry aerothermodynamics studies. The inherent

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advantages that are associated with the novel plasma preheating technology presented herein include but not limited to (1) light weight and portability of model, (2) surface temperature control to replicate re-entries, (3) excellent temperature profile across the surface of sample, (4) capability to replicate entries for different planetary missions due to its ability to perform well in all types of re-entry gases like O_2 N_2, Air, CO_2, He, Ne, Ar, H_2, CH_4, NH_3, etc., (5) capability to experiment different types of heatshield materials like PICA, SIRCA, Avecoats, C/C composites, and graphite to name a few, (6) capability to experiment different axisymmetric probe geometries not limited to Stardust, Orion, Hayabusa, and SpaceX-dragon, (7) capability to perform well in both short and long duration wind tunnel facilities,(8) the technique inherently eliminates arc chamber problems that are associated with most high-enthalpy facilities, (9) the technique inherently produces much lower greenhouse emissions, and (10) the technique is inherently economical and less than 10% of the operational costs of running the high-enthalpy plasmatrons and NASA Ames arcjet facilities.

II. Overview

Reliable heat-shielding is essential, physical re-entry processes are complicated, experiments are needed to support model development, and hypersonic impulse facilities cannot perform ablation tasks if cold-walled [Iyinomen at al 2021]. The aim of this present work is to quantitatively measure the ablation and oxidation rates in a hypersonic boundary layer using a new hot-surface plasma preheating technology to heat to the required surface temperatures for re-entry studies in a hypersonic impulse facility. This is a new experimental method for heating material samples using a high temperature plasma arc fixture. This new fixture was integrated within a cold flow Mach 4.5 wind tunnel in order to measure material ablation and mass loss due to aerodynamic flow effects. This work provides details of the experimental method, few CFD simulation results in support of the experiments, and a series of mass loss measurements and microscopic images to quantitatively and qualitatively observe material mass loss and surface modifications. A temperature of 2500K was achieved in the test specimen [Iyinomen 2020a]. The surface temperature measurements, uncertainty in measurements, temperature variation from stagnation point to the edges (shoulders),and percentage (%) deformation of material sample after test had earlier been published extensively by the author [Iyinomen et al. 2021] and will not be repeated here. The radial temperature distribution along the surface is also available elsewhere [Iyinomen 2022a]. Details on the numerical method, grid, boundary conditions, probe axis along the axisymmetric centre-line (stagnation-line) of the flow, shock resolution, source of the carbon species, surface chemistry/ablation model adopted, the presence of carbon species so far removed from the face of the probe, the unit Reynolds number for the flow conditions, and the motivation for using the same graphite disc for all the final heating runs had already been made available by the author [Iyinomen 2020b].

This work creates a genuinely interesting approach to probing high temperature effects in a cold flow tunnel and documentation of mass loss from their specimens using dimensional values. The quantifiable measurements of mass loss can then be connected to ablation theory or models. The measurement techniques mostly focus on mass loss and recession of the tested graphite disc, applying tools such as the Romer Multi-Gage 6-axis Coordinate Measuring Arm, the laser beam technique, and the Scanning Electron Microscope (SEM) were used to obtain experimental data with focus on ground-based characterisation techniques for thermal protection material analysis. The topic treated in this manuscript is of importance to the international research community, especially in the field of new ground-testing facilities for ablation analysis and in the context of material response model validation. The author is highly pleased to present a new test facility and new measurement technique for the acquisition of data for model calibration/validation. Apparatus development for the new preheating methodology, calibration of camera and spectrometer, and FEA simulations have shown that the determined temperature profile of the heated disc is suitable to continue with mass loss assessments [Iyinomen 2020b, Iyinomen et al. 2021].

Recent experiments based on Orion re-entry conditions used a surface temperature of about 2800 K [Glass 2008] and Apollo 4 lunar return speed of 11 km/s reportedly experienced a surface temperature of about 2400 K [Decand Braun2006], while typical re-entry surface temperatures for Space Shuttles was about 1740 K [Glass 2008]. This present work has achieved temperatures in excess of 2500 K on a preheated graphite surface used for the assessment of mass loss through ablation in a Mach 4.5 flow. The use of a plasma as the means of heating the disc was proven to be effective for reaching temperatures of these magnitudes and the process has potential to be more widely used for similar experiments [Iyinomen 2022a]. This work reports the first-time quantification of ablation and oxidation rates of a heated carbon disc in a Mach 4.5 flow up to 500 milliseconds duration in a hypersonic wind tunnel facility using the preheating methodology [Iyinomen 2019]. Two methods were utilised in the ablation measurements which will be discussed in Section V: (1) weighing method, and (2) volume-based method. The model in the present work can be likened to the European standard probe [Fagnaniet al.2019] positioned at a zero-degree angle of attack to the incoming flow [Zhanget al. 2019], and heated from the downstream side using a plasma to temperatures in excess of 2500K. The separation of the tungsten electrode from the disc surface and the length that the electrode protruded from the shroud had significant effects on the ability to start a plasma. Preheating of the graphite disc was achieved with plasma [Wang et al. 2019, Traidia 2011] generated by a DC current [Siewert et al. 2019, Anand et al. 2017] between a tungsten electrode and the back (downstream) side of the disc. Figure 2 is a sectional view of the model which illustrates the Thermophysics and heat transfer processes from the hot plasma to the disc. The power generating technique is shown in Figure 3.

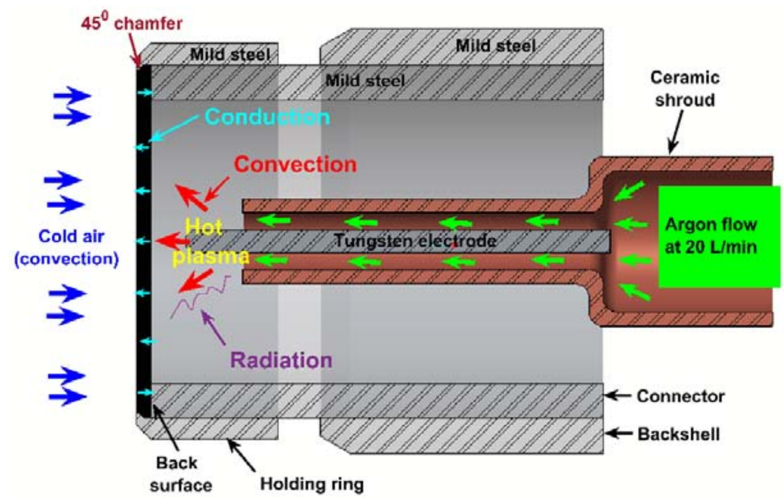


Figure 2: The new plasma preheating technique illustrating the Thermophysics and heat transfer processes from hot plasma tographite disc [Iyinomen 2020a].

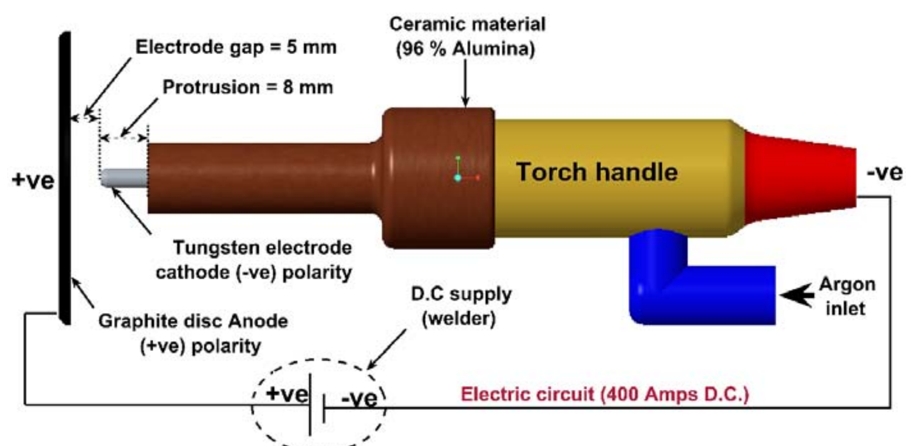


Figure 3: Illustrating electrical heat generation at 400A power rating [Iyinomen 2020b].

The two most critical geometric parameters controlling the heat flux to the workpiece (graphite) are electrodegap and protrusion. The orientation of the tungsten inert gas (TIG) torch is centralised in the model to enable even thermal spread from the centre to the edges. This made it possible for the probe model to assume an axisymmetric orientation. Experimental heating conducted in 500 Pa vacuum pressure, for 15 seconds using the plasma preheating technology is illustrated in Figure4 to preheat model to the desired temperatures (about 2500 K) just before the flow starts. The data from temperature measurements were extracted through the fibre optics.

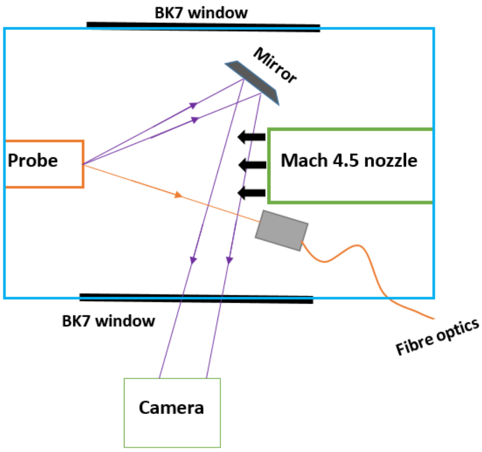
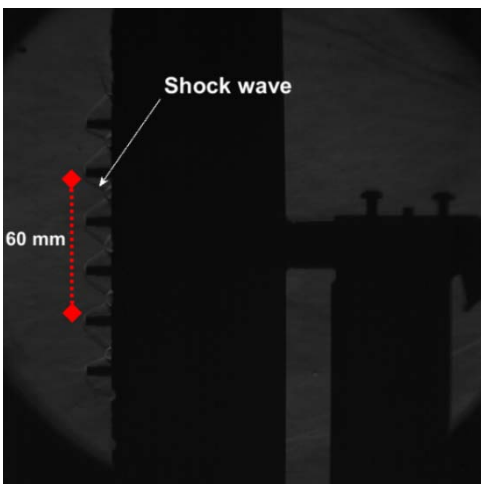


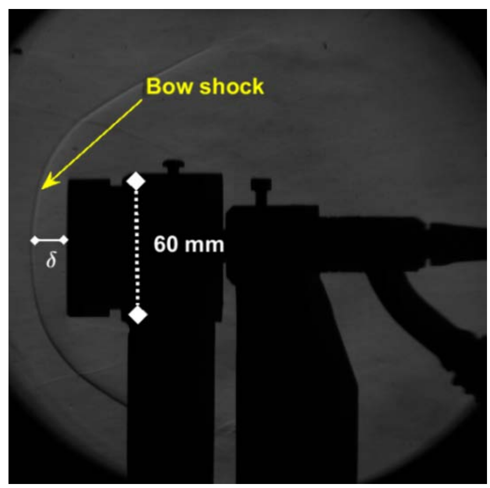
Figure 4: Schematic layout of setups for ablation experiments. Temperature data was made available via fibre optics and connected to the data acquisition system for data extraction and processing [Iyinomen et al. 2021].

III. Methodology

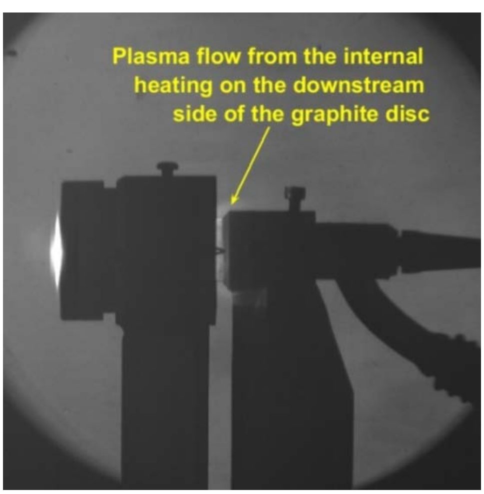
An accurate assessment of the duration of the flow in the experiments is essential for accurate evaluation of the mass loss rate. The TUSQ data acquisition system (DAQ), automatically saves the run times which allows the duration of each run to be determined [Birch et al. 2018]. Confirmation of the flow characteristic of the nozzle (nozzle start) was supported by Schlieren high-speed video images [Settles 2006]. Knowing the mass losses and using the run times from the DAQ, the average material loss rate was determined. For each of these sets of runs, the total duration and total mass loss were used to determine the mass loss rates. The Schlieren images in Figure 5 show the orientation of the experimental modelrelative to the pressure survey system, which was used to characterise the flow properties. The Schlieren images forthe three classes of tests (flow-only case, heated-only case, and heated-with-flow case) were used in the present work.



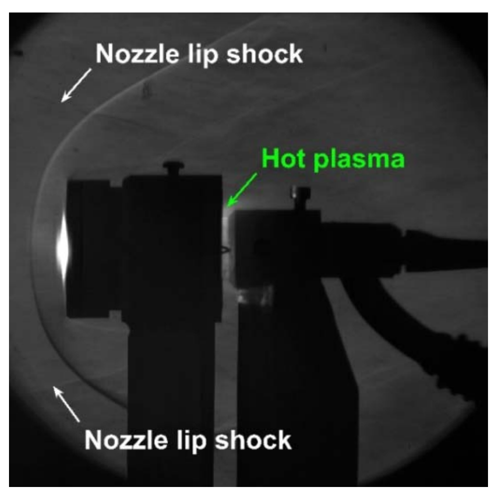
(a) Pressure survey array at Mach 4.5.



(b) Flow-only case at Mach 4.5.



(c) Heated-only case at 2500K.



(d) Heated-with-flow case at 2500K and Mach 4.5.

Figure 5: High-speed camera Schlieren imaging was used for aerodynamic validations, where the heated-only case was taken at about the time flow would normally starts [Iyinomen 2019].

1. *Flow-Only Case:* The disc used in the flow-only case was placed in the holding ring. The test section was sealed and the vacuum pump operated for approximately 20 minutes to reduce the test section pressure to approximately 500 Pa. No preheating was applied before the main valve was operated to produce the flow. Flow durations were typically 0.5 seconds.
2. *Heated-Only Case:* The disc holder surfaces were cleaned and the disc installed. A new electrode was placed in the TIG torch and the TIG settings required for the plasma were applied. The test section was sealed and vacuum pumps operated and after the 20 minutes required to reduce the test section pressure to approximately 500 Pa, the run was commenced by initiating the plasma. The plasma heated the disc for 15 seconds, manually timed. No flow was used in this case.
3. *Heated-With-Flow Case:* The disc was set up and heated for 15 seconds as per heated-only case. The flow was initiated after 15 seconds of heating, manually timed. The heating remained on during the entire flow duration of about 0.5 seconds. The Schlieren technique based on the principle of changing densities in the gas was used to identify the establishment of the bow shock and therefore the commencement of Mach 4.5 flow. The high-speed camera was set at a frame-rate of 2500 fps and frames at the specific points during the flow are shown in Figures 6 and 7.

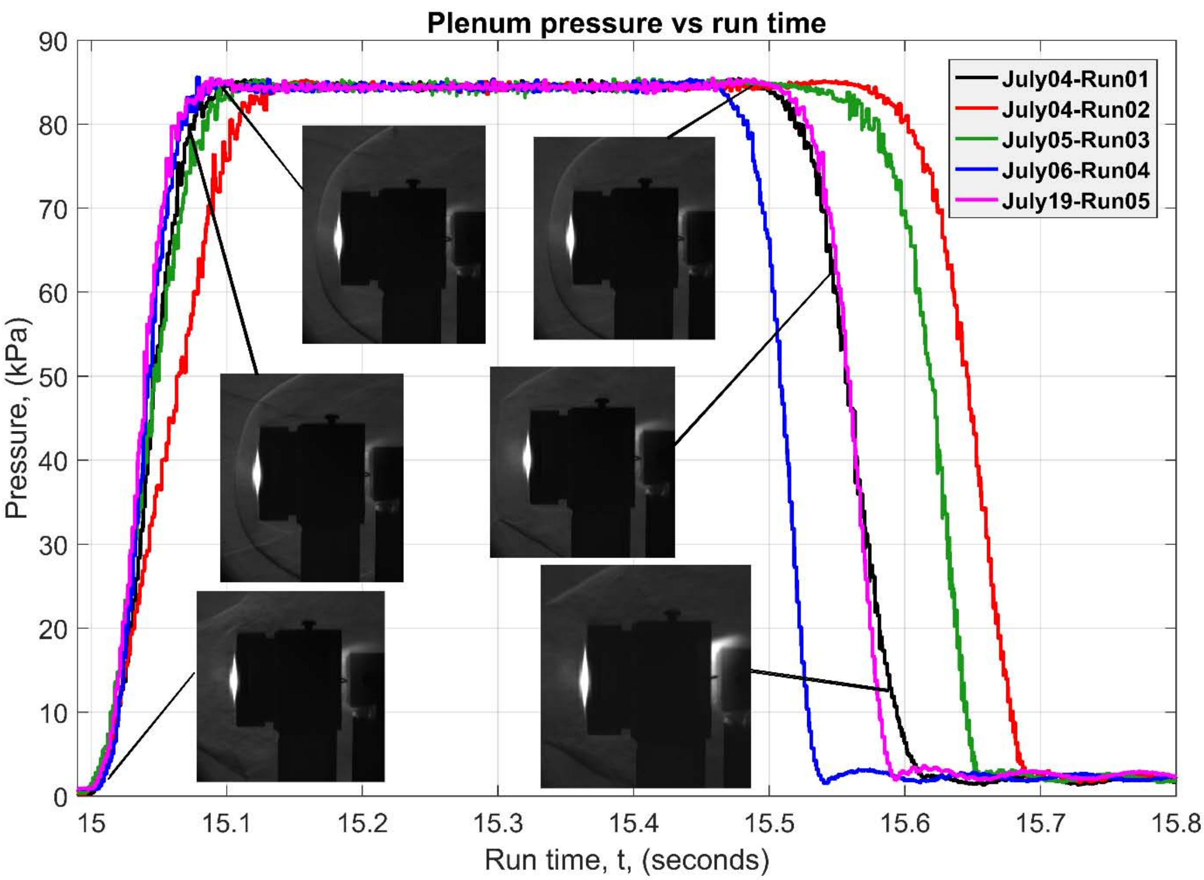


Figure 6: Matching run times with Schlieren images to identify when flow starts [Iyinomen 2020a].

The start and end times for the sixteen (16) heated-with-flow runs for the second phase of the experiments are shown in Figure 7. The shortest run time was 0.45 seconds while the longest was 0.64 seconds. This gives an average run time of 0.54 seconds for a 16 heated-with-flow run.

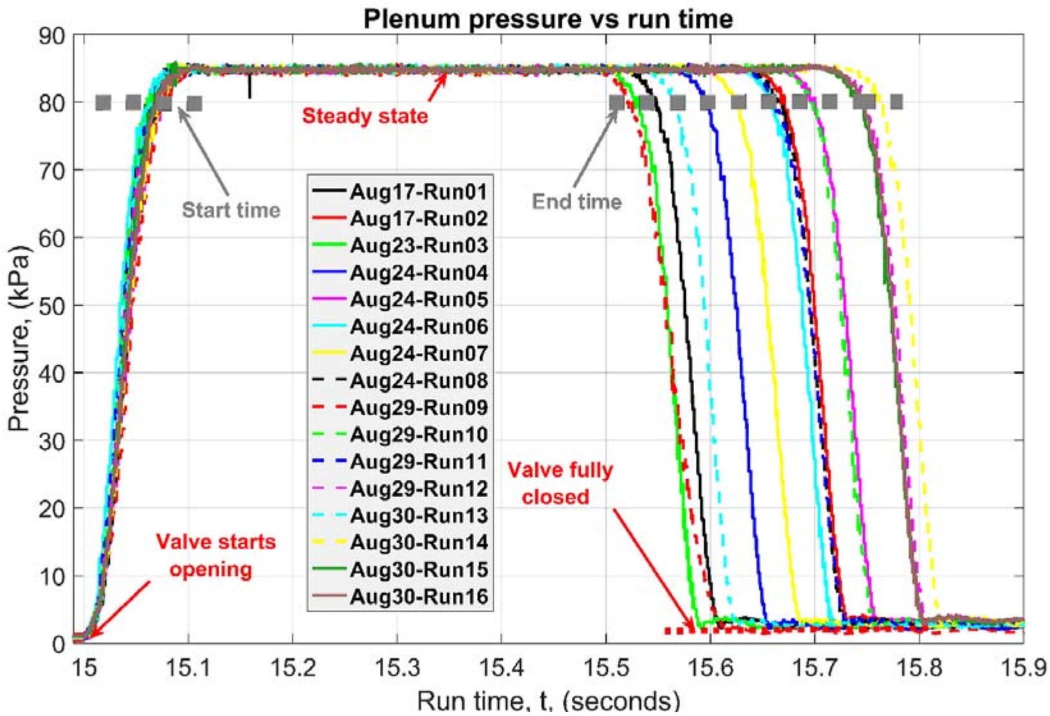


Figure 7: The start and end times from the 16 heated-with-flow run of the experiments used to determine material loss rates. Mass loss was measured for each of runs 1 and 2, then at the end of runs 4, 8, 12 and 16 [Iyinomen 2020a].

Analytical methods were used to estimate the power requirements for preheating the samples. The result from analytical methods was compared with the calibrated data from previous work as shown in Figure 8. The current ranged from zero to 700 Amps because the maximum output from the welding machine was 700 Amps at the time of experiments. The heating starts from ambient temperature and the poly-fit was obtained by applying the Least square fitting for second-order polynomials to the calibrated temperature data at 200, 250, 300, 350, and 400 Amps. Figure 8 shows that the calibrated surface temperatures have good agreements with the estimated surface temperatures.

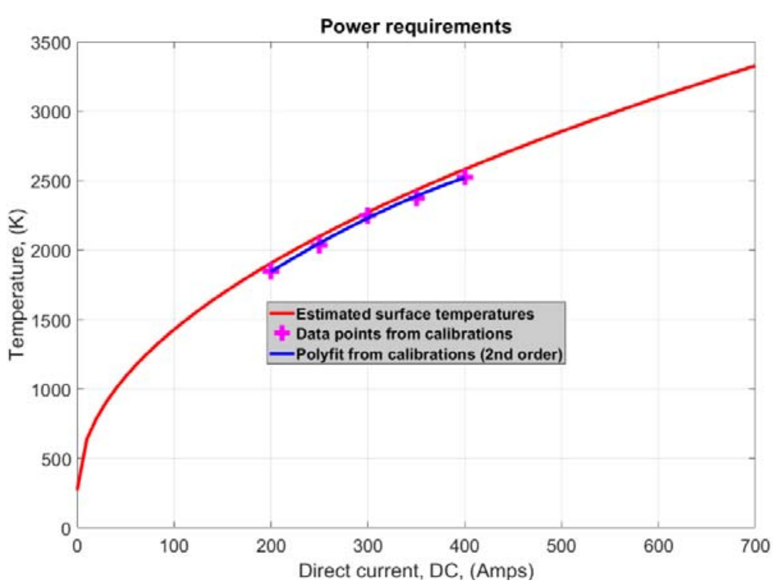


Figure 8: Power requirements for preheating ablation samples [Iyinomen 2022a].

IV. Flow Properties and Species Transports

Flow properties associated with the present work were obtained from CFD simulations using ANSYS Fluent. Surface temperatures and boundary conditions in the CFD were set using measurement information from experiments. Figure 9 indicates that the temperature has not changed significantly until within 1 mm from the wall, so the concentration of products was not entirely driven by temperature alone.

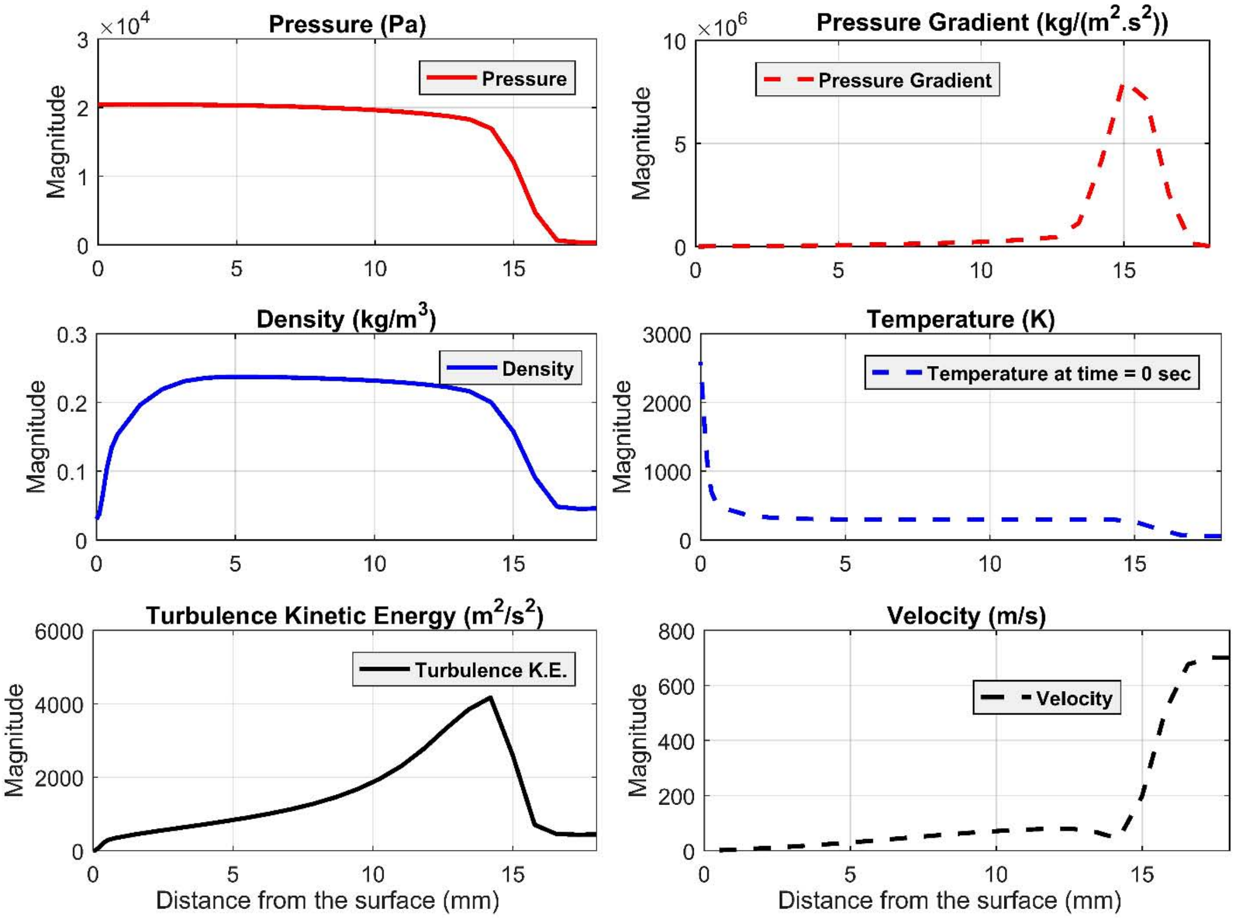


Figure 9: Flow properties along the probe axis stagnation line from CFD simulations [Iyinomen 2020b].

Species transports are driven by flow properties. Thermally initiated chemical reactions are the formation process of all carbonaceous species in Figure 10 except for the carbon sublimation species, C, C_2, C_3. The CO_2 species are formed from further oxidation of CO species, thus making CO_2 a secondary reaction. The CO_2 concentration shows a maximum at the stagnation flow region where the O species are maximum, which suggests the requirement of O species for CO_2 formation. The result also shows that CO_2 has a sharp drop from the peak value to almost zero at the surface within the experimental temperature limit of 2530 K. The CN species distribution also shows a similar pattern to that of CO_2. This also suggests that CN is not a product of direct surface reaction within the experimental temperature limit. This further supports the absence of dissociated nitrogen atoms which would otherwise aid direct formation of CN at the surface. However, another possible path for CN production is through CO produced by the ablation reactions CO+N → CN+O [Martin at al 2010]. The sublimation species C, C_2, and C_3 were almost zero.

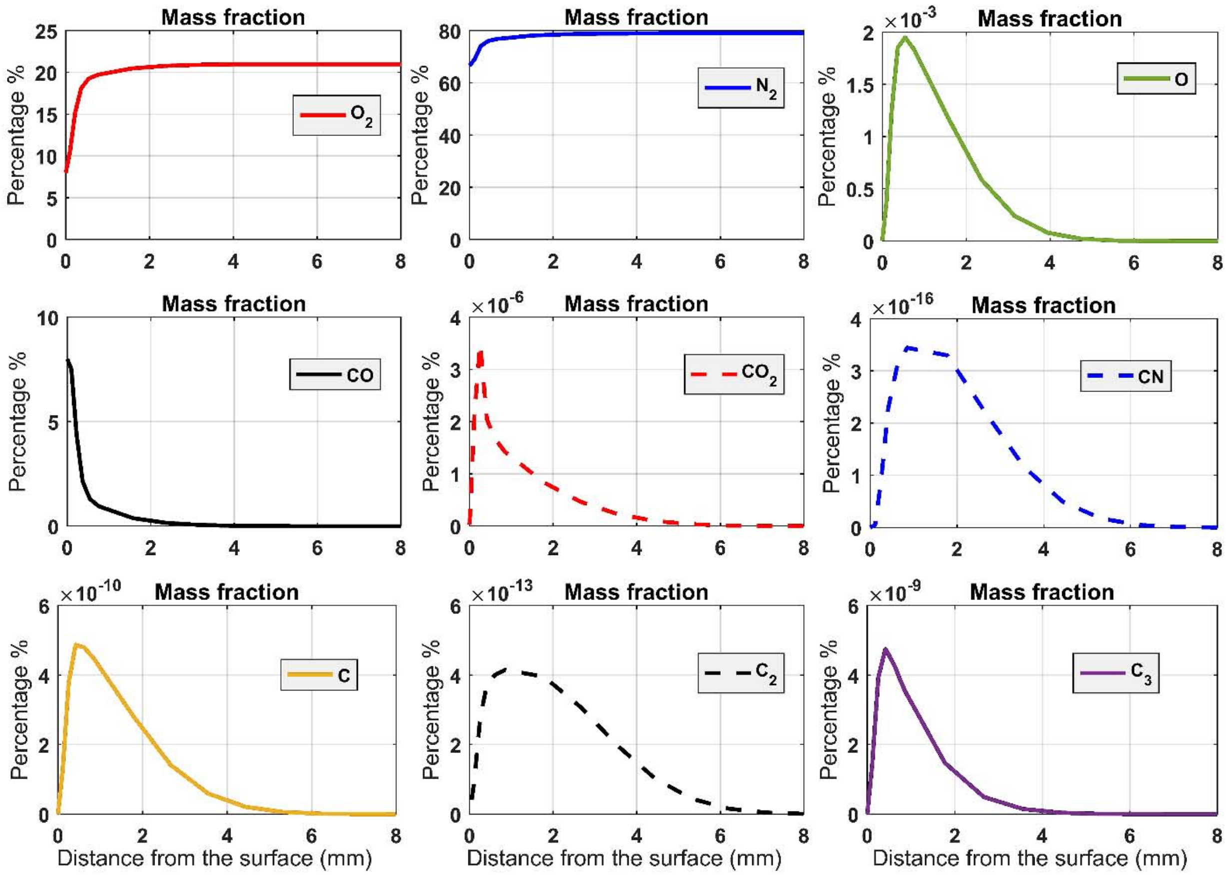


Figure 10: Species mass fractions along probe axis stagnation line- CFD simulations [Iyinomen 2020b].

The graphite ablation sample used in the present work is an iso-statically pressed graphite with grade PCC-X2 from Graphite Australia. Oxidation analysis of other materials can be made by simply reproducing the methodology and replacing the disc material properties in the simulation. The moral justification and materials properties of the graphite specimen has been published extensively by the author [Iyinomen 2020a]. Unlike the negative heat flux to the wall from the flow in high enthalpy facilities, the present work adopts a positive heat flux from the wall to the flow [Iyinomen 2022b].

V. Experimental Procedures

a) *Experimental Mass Loss Measurements using Mass Weighing Method*

Using the arrangement of the experiment described in Figure 5, experimental runs were conducted using three (3) different cases in two (2) phases. The first phase (phase 1) of the experiments involved different runs using random discs, while the second phase (phase 2) was more coordinated using same disc specimen throughout the sixteen (16) heated-with-flow runs. Each run required the disc to be removed for measurement and/or cleaning of the holding ring. This required the test section to be opened after each run. The experimental procedures for the final phase (phase 2) involved the following steps in a chronological sequence.

1. Graphite disc was prepared using a centre lathe by parting from a 50 mm diameter bar. Only one disc was used during the final experiments.
2. The disc was sanded by hand on emery paper against a machined flat surface to remove machining marks.
3. The disc was weighed using a mass balance.
4. The disc thickness at various positions was measured using a micrometre gauge.
5. A visualisation technique using a laser sheet produced an image representing the profile of the surface.
6. A Scanning Electron Microscope was used to show the surface texture at various positions on the disc.
7. The measured disc was subjected to one flow-only case and processes 3 to 6 were repeated.
8. The same disc was subjected to one heated-only case and processes 3 to 6 were repeated.
9. The same disc was subjected to the first of sixteen heated-with-flow runs and processes 3 to 6 were repeated.
10. The same disc was subjected to a second heated-with-flow run and processes 3 to 6 were repeated.

11. The same disc was subjected to another two heated-with-flow run after which, processes 3 to 6 were repeated.
12. The same disc was subjected to three series, each of four heated-with-flow runs and after each series, processes 3 to 6 were repeated.

To measure the degree of ablation losses, the mass loss during the experiments (flow-only, heated-only and heated-with-flow) were measured using a Kern ABT mass balance. The balance displays at an increment of 0.00001 g and reproduces a weighed mass at a resolution of 0.0001 g. The mass loss during each test was the difference in readings before and after the tests. At each weighing, the disc was placed on the balance and the machine automatically detects when the reading is stable, at which time the weight was recorded. The disc was removed from the balance, then replaced and a new weight recorded. This was repeated to record a total of three weights, which were averaged with an attributed uncertainty specified as the maximum difference between the average and any of the three recorded weights. Table 1 shows the disc mass loss for all the runs in the second phase of the experiments. Both phase 1 and phase 2 test data are presented in order to obtain a general comparison of all experimental data for same set of conditions at different times.

Table 1: Experimental data obtained from mass loss experiments from Phases 1 and 2.

Flow-only case		Heated-only case		Heated-with-flowcase	
Mass loss (g)	Run time (s)	Mass loss (g)	Run time (s)	Mass loss (g)	Run time (s)
Phase 1: Pre-test Data – several random discs were used for all three (3) cases					
0.000544	0.58	0.00816	15	0.0164	0.458
0.000475	0.51	0.00820	15	0.01735	0.480
0.000583	0.55	0.00812	15	0.01766	0.495
0.000525	0.53	0.00792	15	0.01767	0.520
0.00051	0.50	0.00803	15	0.01802	0.530
-	-	0.00806	15	0.019221	0.540
-	-	0.00810	15	0.01933	0.540
-	-	0.00799	15	0.01984	0.550
-	-	0.00802	15	0.02002	0.560
-	-	0.00830	15	0.02042	0.569
-	-	0.00822	15	0.02065	0.570
-	-	-	-	0.02083	0.580
Phase 2: Final Test Data – same disc (newly prepared) was used for all three (3) cases					
0.00050	0.495	0.00790	15	0.0138	0.450
-	-	-	-	0.0167	0.460
-	-	-	-	0.0373/ 2 runs	0.960/ 2 runs
-	-	-	-	0.0746/ 4 runs	2.200/ 4 runs
-	-	-	-	0.0811/ 4 runs	2.240/ 4 runs
-	-	-	-	0.0831/ 4 runs	2.240/ 4 runs

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From Table 1, the average mass losses for flow-only, heated-only and heated-with-flow cases were 0.000527, 0.0082, and 0.0190 g respectively. The average mass loss rate, $\dot{m}_{loss}$ for the flow period of a heated-with-flow run is represented by Eq. (8), where Δm is the difference between the average mass loss from heated-only and the average mass loss from heated-with-flow runs. The parameter Δm accounts for the actual mass loss during the realflow period from the heated-with-flow runs with an average run time Δt of 0.54 seconds for this flow period. This actual mass loss during the flow period is reasonable because all heated-with-flow cases had undergone the heated-only stage before the flow was initiated.

$$\dot{m}_{loss} = \frac{\Delta m}{\Delta t} = \frac{0.0190 - 0.0082}{0.54} = 0.020\ g/s \quad \text{Eq. (8)}$$

Figure 11 presents the experimental results for the flow-only cases. The average mass loss rate for flow-only case was on average 0.0010 g/s. The mass loss itself for flow-only case was an average of 0.000527 g, which represents about 2.8% to the overall ablation for the heated-with-flow runs. It represents 4.9% of the ablation that occurs during the flow in a heated-with-flow run.

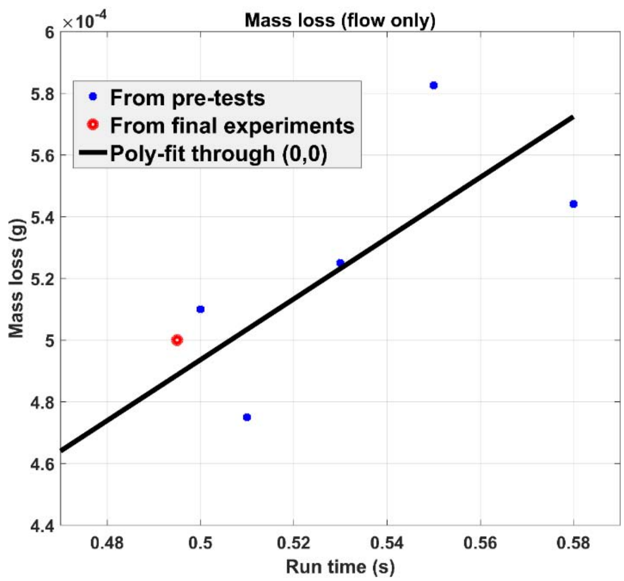

Figure 11: Plots of mass losses for flow-only cases. The datum point for the flow-only case at the start of the final 18 runs is depicted with a red-dot marker type. The mass lost rate is depicted by the slope of a linear best fit line forced through the origin, giving a mass loss rate of 0.00099 g/s.

This flow-only mass loss resulted without any chemical reactions, thus suggesting that mechanical actions were not insignificant, but only a minor contributor. For the heated-only experiments as shown in Figure 12, dividing the accumulated mass losses from the twelve different heated-only runs by the total time of heating, produces a mass loss rate. This assumes a constant mass loss rate during the heating cycle, but the temperature increased during a cycle from 0 to 15 seconds. The mass loss rate will be dependent on temperature, so a mass loss rate as a function of temperature is not obtainable from the heating only data. The average mass loss rate during a heating only run was 0.00055 g/s. A more useful value is the average mass loss per heating cycle, as the heating cycles were consistently of the same duration of 15 seconds. The average mass loss per heating cycle was 0.0082 g. The average mass loss due to the heating cycle was about 43% (0.0082/0.0190) of the overall ablation for the heated-with-flow run.

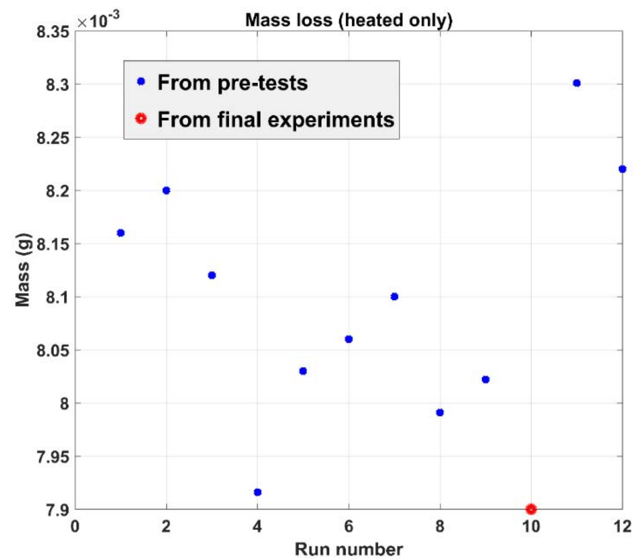

Figure 12: The results for heated-only mass loss during 15 second heating cycles.

Figure 13 shows the mass losses from sixteen heated-with-flow runs, completed at six stages (see experimental procedures 8 to 12 in Section V). The flow run time varied from 0.45 seconds to about 0.56 seconds, with a target of 0.5 seconds. The time variation was due to the manual opening and closing of the flow control valve. The mass loss shows a general increase with increasing run time. The result from step 6 shows an increase in mass loss over that of step 5 despite the same run time. This difference might be attributed to the crack, which potentially exposed more graphite material to ablation [Iyinomen 2020a], although the difference is not outside the range of the error indicated by the best fit shown in Figure 13. The red line shows the best-fit (linear fit) of which the slope is about 0.020 g/s running through point (0,0.0082), as there is already a mass loss of about 0.0082 g when the flow starts. The value 0.0082 g was obtained from the average of the heated-only experiments. It is reasonable to apply this average as the heating time was consistently the same. The

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displayed flow durations for the series of heated-with-flow runs are the averages for those series.

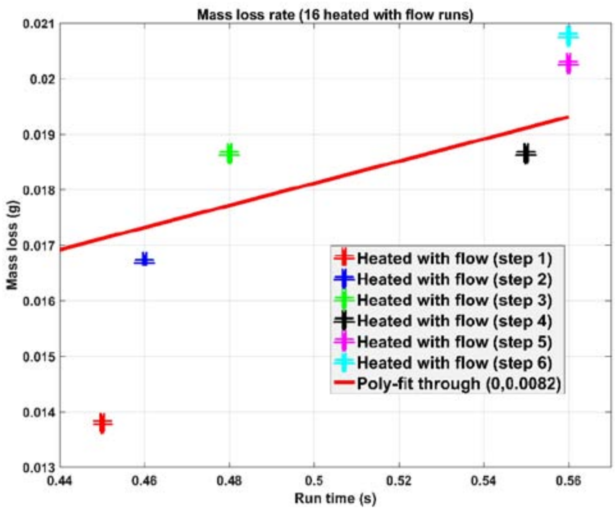


Figure 13: Result showing the mass losses for the flow period from heated-with-flow runs. The slope of the poly-fit line represents the average mass loss rate of 0.020 g/s.

As a check of the data reproducibility of the sixteen heated-with-flow runs, analysis of earlier heated-with-flow runs was carried out. Figure 14 also shows the results of the mass losses from other heated-with-flow runs from earlier experiments using pre-test data from Table 1. The mass loss rates ranged from 0.034 g/s to 0.036 g/s with an average of about 0.035 g/s. It was calculated based on the slope of a linear best fit of the plot in Figure 14, again going through the point (0,0.0082) as applied for the final 16 runs.

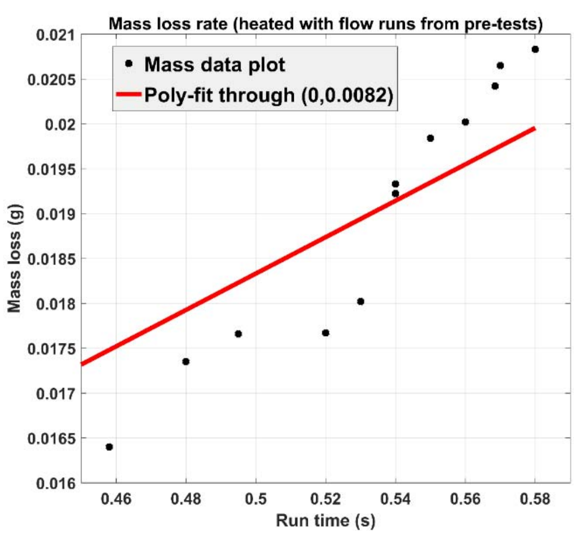


Figure 14: Result showing the mass losses from the heated-with-flow runs during pre-tests. The slope of the poly-fit line represents to average mass loss rate of 0.020 g/s.

b) Experimental Mass Loss Measurements using Volume-based Method

The measurements with the Romer Multi-Gauge 6 Axis Coordinate Measuring Arm (Part Number: NCA7-05-16186) proved effective in determining the shape of the surface of disc. The measurements were taken along three radii, R1, R2 and R3. Where R1 and R2 were taken along a diameter, and R3 was taken in the direction that is perpendicular to the diameter as shown in Figure 15. An average of nine measurements were taken along each radius.

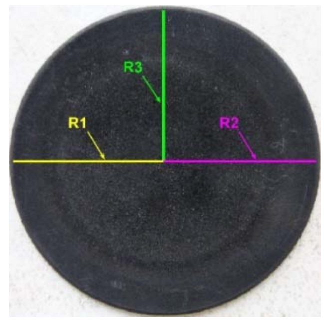


Figure 15: The image of disc was defined by three radii R1, R2 and R3.

Referencing the back surface as facing the plasma and the front surface facing the flow, the thickness of the disc was determined from data obtained on various paths as shown in Figure 16. Disc thickness was defined by the measurements along the three radii on the front of the disc in relation to measurements at the same positions on the backside of the disc. The advantage of using three radii was to get data to identify the precision with which the shape was measured and therefore give data to provide an estimate of the uncertainty with which the shape and mass loss were measured. The measuring arm was only used at the end of the whole series of experiments and not after each run because the required contact to take the measurements would damage the surface and effect the subsequent ablation. Figure 16 shows the relative heights of positions along R1, R2, and R3 at the back and front of the disc. The paths along the back appears to be more consistent when comparing the three radii than the paths along the front. The change in height on the back surface, due to the heating, produces a smoother profile than is evident on the front surface subjected to ablation.

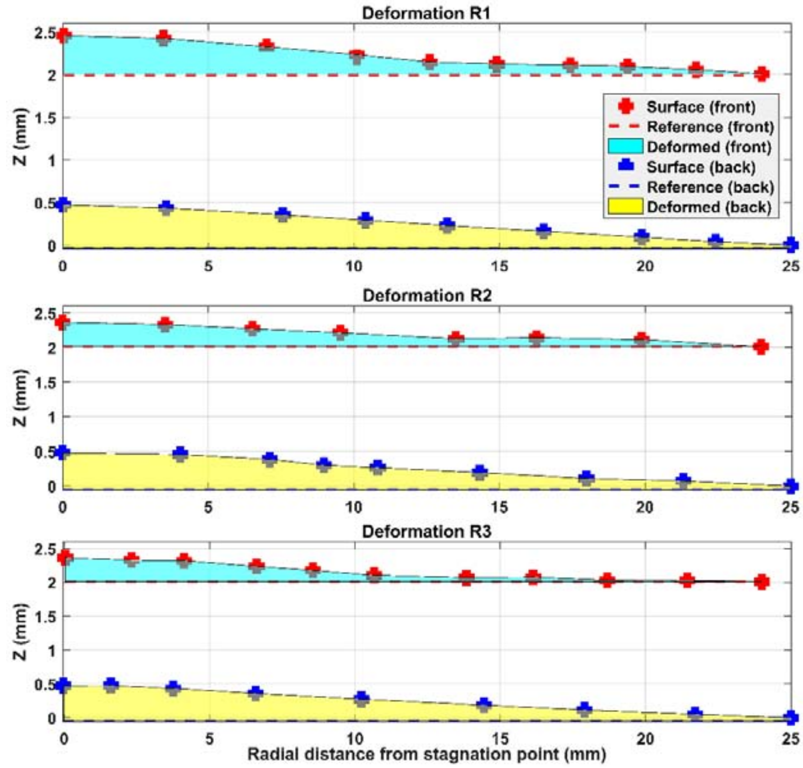


Figure 16: Measurements of the front and back of the disc along paths R1, R2, and R3 after experiments.

Using Figure 16, an average of the thickness at positions along the three radii was calculated and the value was used for calculation of thickness reduction based on an axisymmetric assumption. One end of each radius was the stagnation point; measurements at this common point were necessarily the same. The ends of the radii at the outer edge of the disc were not relative to any particular reference in the raw data taken from the measuring arm. The thickness at these points was obtained from the micrometre measurements and the relative positions along each radius were respectively adjusted. The data in Figure 17 shows the loss in thickness of the disc along R1, R2 and R3. Starting from the edges, the thickness reduction progressively increases to about 12 mm to the stagnation point in the radii direction. The thickness reduction along R1, R2 and R3 was highest between 0 to 12 mm to the stagnation point. The average thickness reduction was about 0.045 mm at the edges and 0.147 mm at the stagnation point. The shaded area shows the profile of material lost from ablation effects. Error bars were calculated using the maximum deviation from an average of data at the various radial positions along the three paths. The data points indicated that there were variations between measurements at the various radial positions along the three radii. The trends are similar along each path, with most deviation from the average occurring in the regions of maximum material loss.

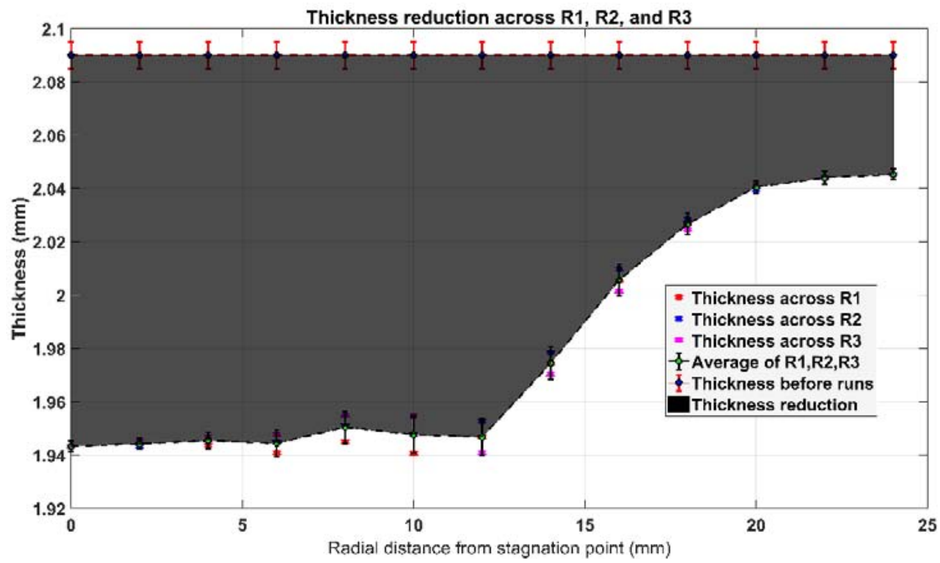
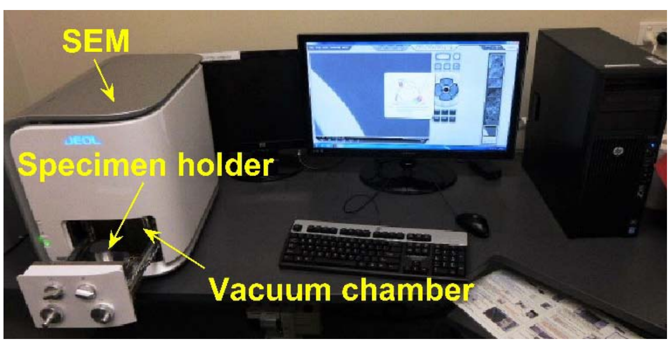


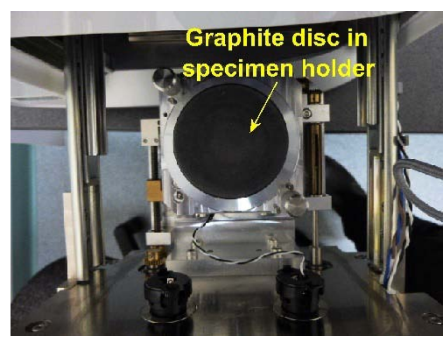
Figure 17: Thickness reduction along paths R1, R2, and R3 after sixteen heated-with-flow experiments.

VI. Surface Roughness of the Disc

The present work does support reasonable contributions to re-entry studies. The experiments show a significant spatial variation in thickness loss for the graphite test material over the disc radius though the spatial variation was still largely axisymmetric. Figure 18 shows the setup for surface analysis using Scanning Electron Microscope (SEM).



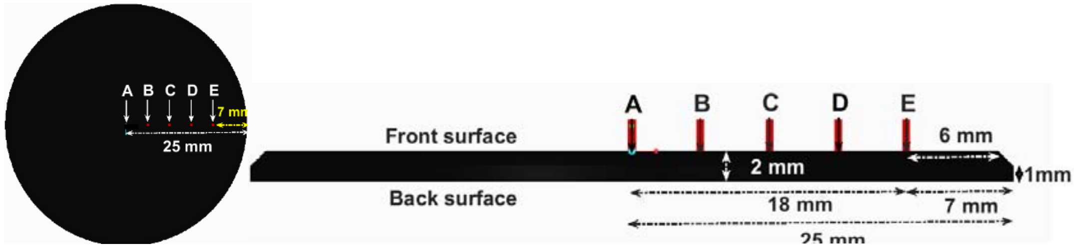
(a) SEM arrangement.



(b) Disc sample in vacuum chamber.

Figure 18: Setting up and mounting graphite disc in the SEM for surface analysis.

The total area able to be scanned by the SEM was limited: the maximum field of view at the amplification used, was 500 μm. The maximum travel of the specimen holder was 36 mm (18 mm $\times$ 2). Five positions were chosen and used for analysis after each series of runs. The disc was placed in the holder in the same orientation for each set of scans. The centre of the disc was determined by traversing the holder to view the edges of the disc with the y-axis displaced so the extent of travel viewed the edges of the disc, then centring the disc based in these limits. This identified position A in Figure 19 and allowed for 18 mm of travel along the radius of the disc. Five positions in total were chosen at 4.5 mm increments, shown as A, B, C, D, and E in Figure 19. This resulted in position E being 7 mm from the outside edge of the disc (6 mm from the chamfer used to retain the disc).During experiments, the actual points scanned in the SEM were not exactly the same; each scan was a representative area in close proximity to the points described by A, B, C, D and E.



(a) Graphite specimen - top view. (b) Graphite specimen - side view (not to scale).

Figure 19: Schematic illustration of scanning locations on graphite surface.

The SEM system has the capability of producing data which describes the degree of surface roughness. The SEM machine could analyse the relative height across a reference line [Iyinomen 2019]. The SEM data for the surfaces were extracted and plotted as summarised in Figures 20 and 21.

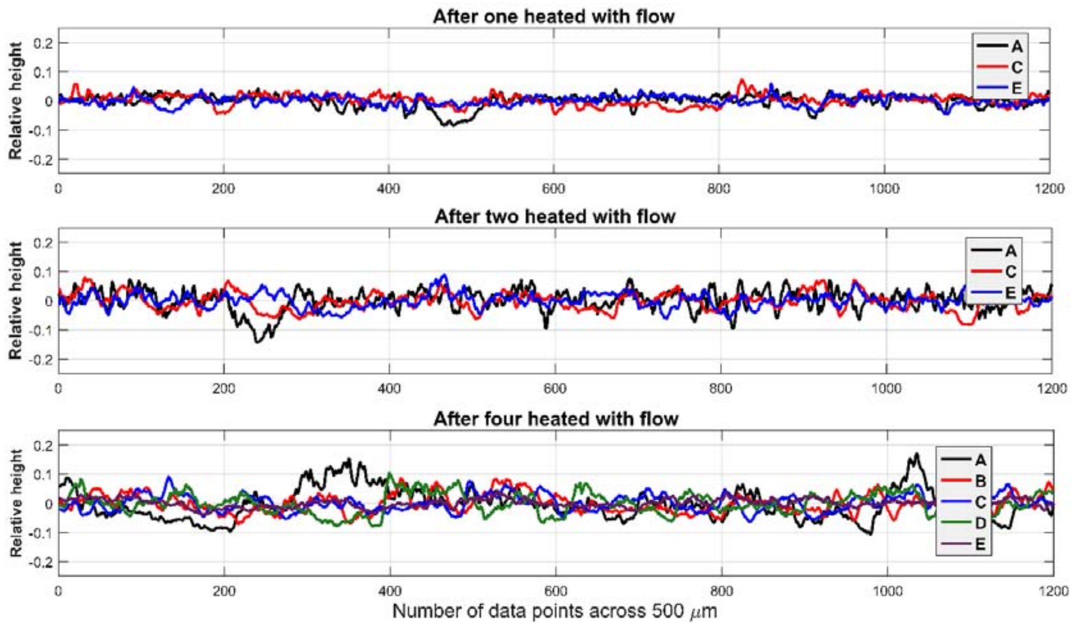


Figure 20: Surface texture relative height summary after 1, 2 and 4 heated-with-flow runs.

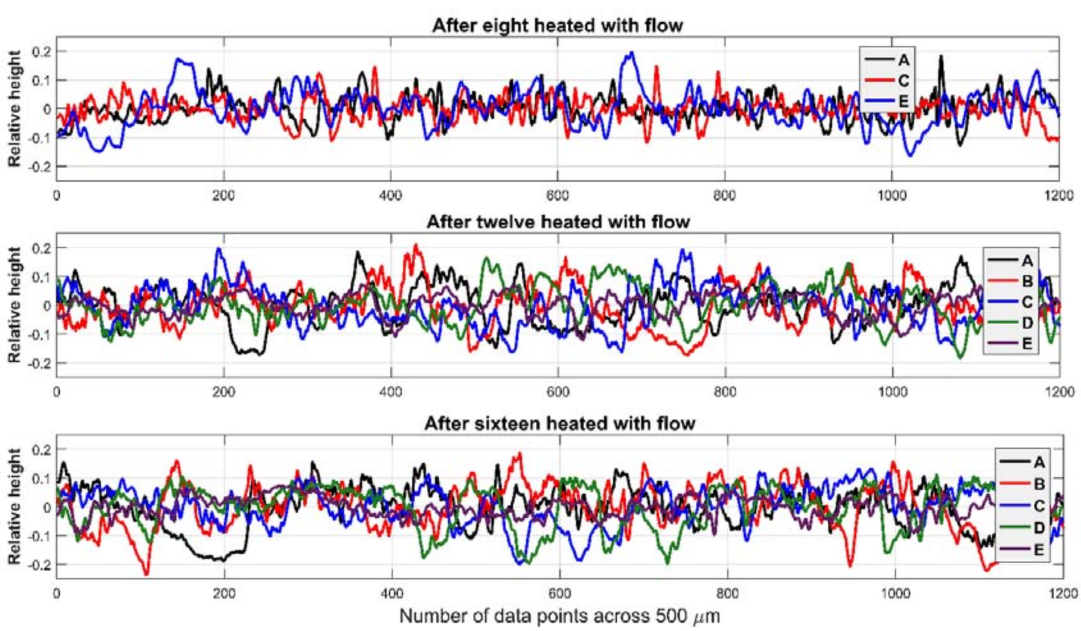


Figure 21: Surface texture relative height summary after 8, 12 and 16 heated-with-flow runs.

Arithmetic average height parameter was used to estimate the surface roughness of the disc. Two basic parameters defining the surface roughness are: (1) maximum height of peaks which defines the maximum height of the profile above the mean line within the assessment length, and (2) maximum depth of valleys which defines the maximum depth of the profile below the mean line within the assessment length [Gadelmawlaet al. 2002]. Determination of roughness using the arithmetic average R_a, defines the deviation of roughness irregularities from the mean line over a sample length n, as shown in Equation 9 [Smith et al. 2003], where y_i is the height at each pixel position along the line profile and $\bar{y}$ is the mean height.

$$R_a = \frac{1}{n}\sum_{i=1}^{n}|y_i - \bar{y}| \qquad \text{Eq. (9)}$$

The degree of surface roughness increases with increasing number of runs, suggesting that potentially larger fragments of carbon are being removed, or the surfaces at the bottom of the valleys are more prone to the ablative actions than those at the peaks. In addition to reducing thickness (increased total material removal), if the increased removal of material from the valleys is occurring, this suggests that chemical reactions are more involved than mechanical erosion. There appears to be a general correlation between the number of runs and the degree of surface roughness as shown in Figure 22. Each point of surface roughness was obtained by averaging the relative heights at each at point C at each SEM measurement. Point C is shown as it is indicative of the ablation changes to the surface involving heating and flow effects. The surface topographies of the disc sample at successive runs for the phase 2 experiments are available in other materials published by the author [Iyinomen 2019, Iyinomen 2022b].

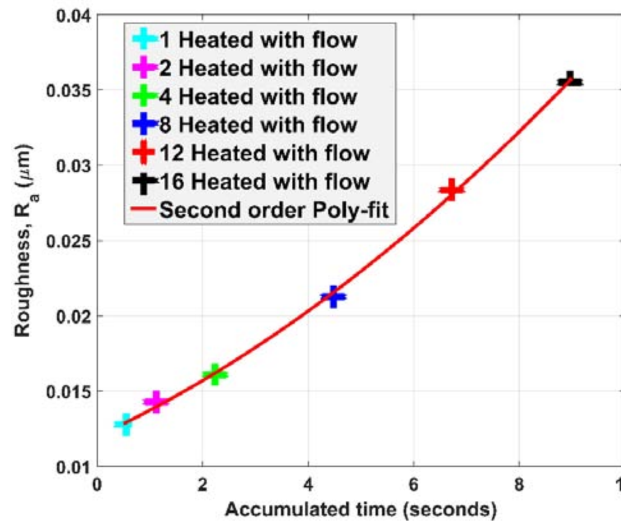


Figure 22: Surface roughness summary from SEM measurements after 1, 2, 4, 8, 12 and 16 heated-with-flow.

VII. Limitations using the Species Spectrometer Measurements

The section does not provide ablation measurement data using species spectrometer but explains why the available spectrometer was not successful for ablation measurements at the time of experiments. Figure 23 shows the experimental setup for ablation experiments using Mach 4.5 nozzle in the blowdown configuration, while Figure 24 shows the analytical CFD and Schlieren imaging from an experimental run.

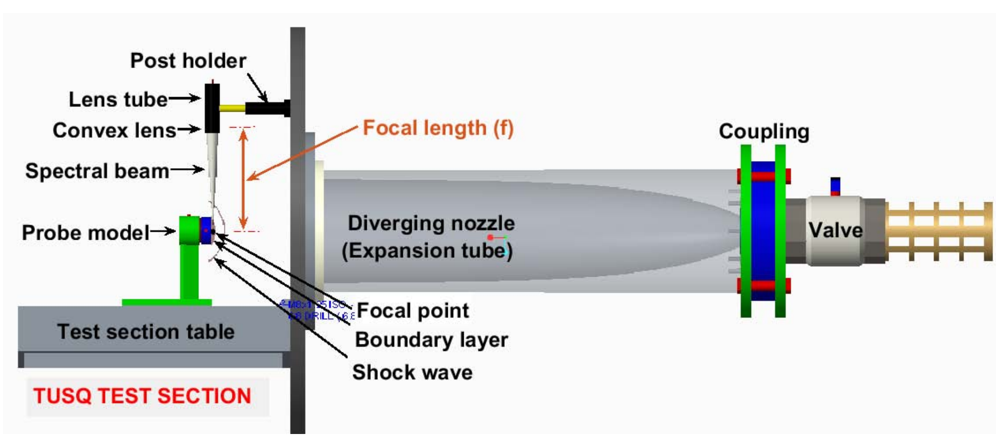


Figure 23: Experimental setup for ablation experiments at Mach 4.5 in the blowdown configuration.

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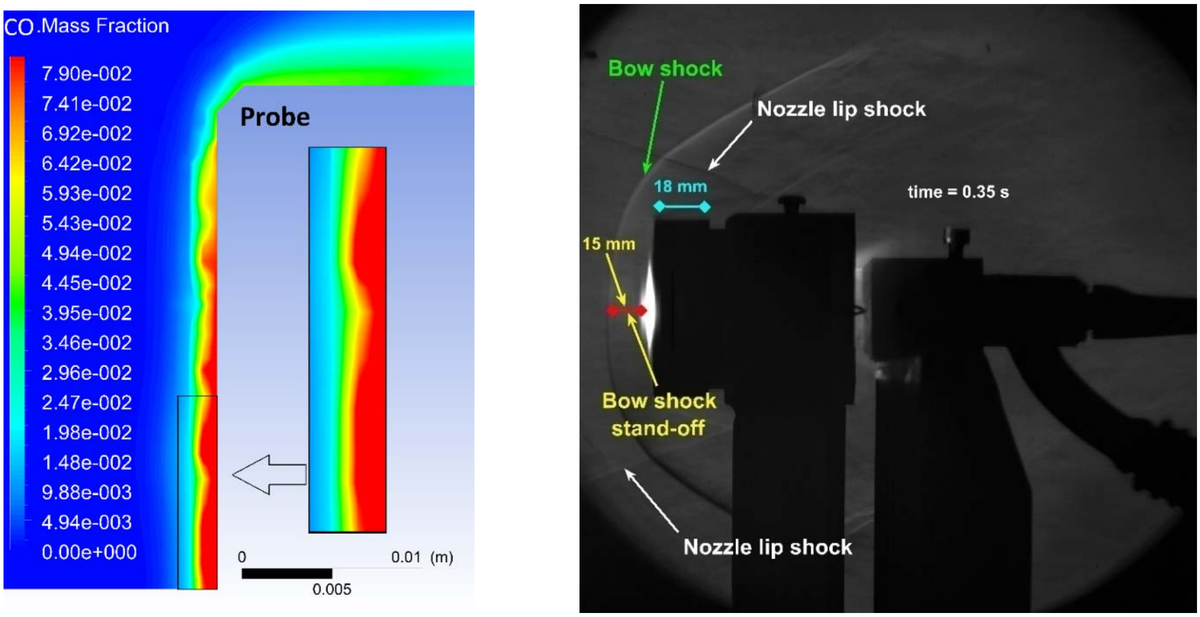

(a) From ablation simulations. (b) From ablation experiments.

Figure 24: Analytical results and experimental run during ablation experiments. The CO_2 mass fraction was about six orders of magnitude lower than that of CO [Iyinomen 2020b].

Figure 25 shows two spectrometers, (1) the Thorlabs CCS175 spectrometer (red) and (2) the Avantes Miniature NIR Spectrometer (blue). The Thorlabs CCS175 spectrometer had a wavelength in the range of 500 - 1000 nm, while the Avantes miniature NIR spectrometer had a wavelength range of 900 - 1750 nm.

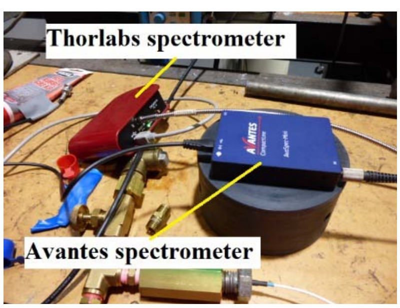

Figure 25: Available species spectrometer at the time of ablation experiments.

Both of them had no moving parts and neither of them could produce good signal for qualitative and quantitative analysis of the surface species. The major reason was because of the background noise. The reacting boundary layer was hot-walled to a cold Mach 4.5 flow. The boundary layer temperature, thickness, species concentrations, type of lens, and potential signal strength were all checked to align with instrumentation and measuring specifications. Figure 26 shows the processed signals from Thorlabs CCS175 spectrometer, while Figure 27 shows the measured and smoothed signals from experiments. These signals were too weak for the author to obtain a high degree of confidence.

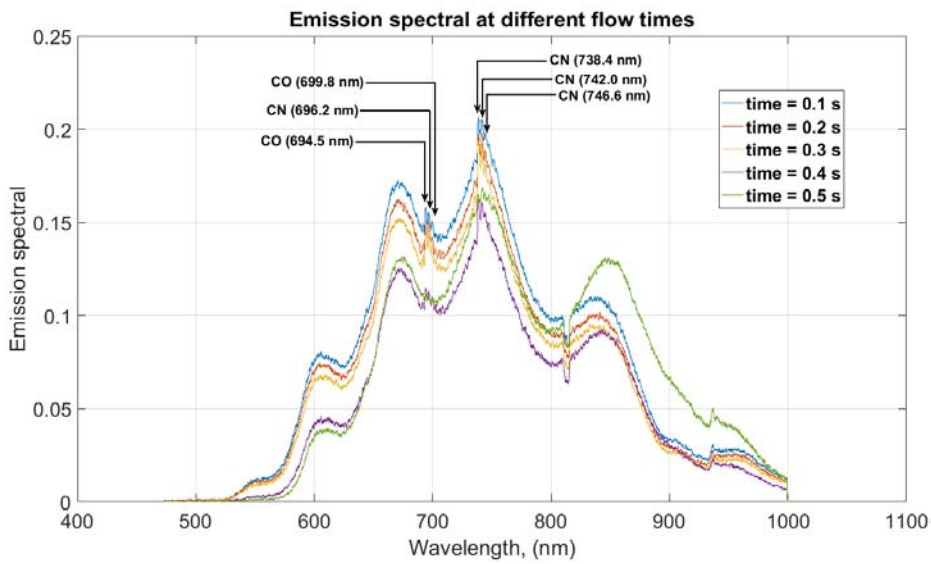

Figure 26: Processed signal from species spectrometer.

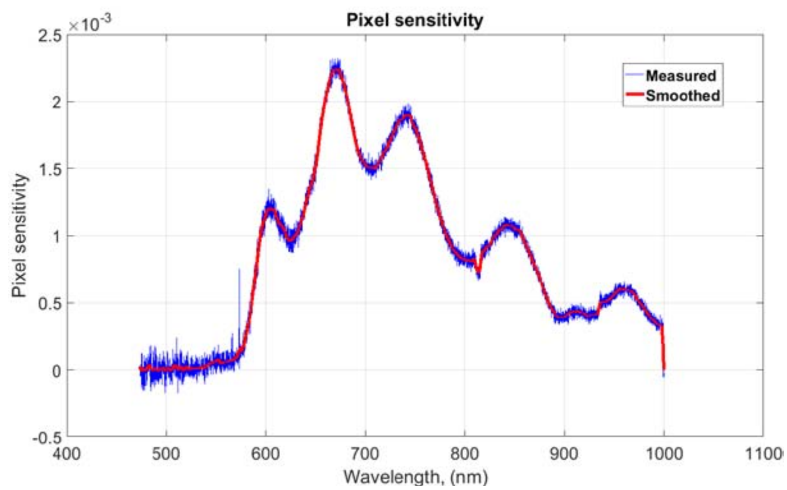

Figure 27: Spectroscopic data showing measured and smoothed signals from experiments.

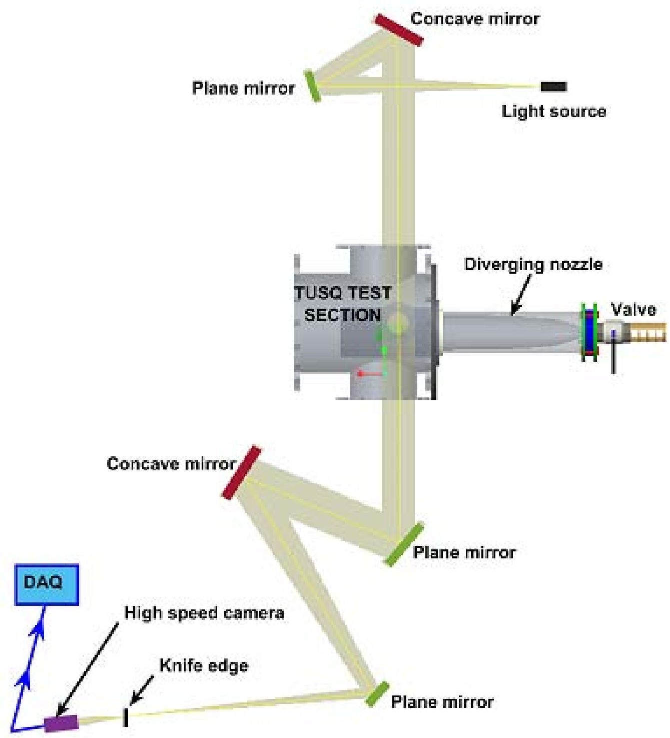

Figure 28: Schematic illustration of the detailed setup for schlieren imaging during experiments.

The author strongly suggests the use of more sophisticated species measuring spectrometers for future experimental programs. The spectrometer should be equipped with liquid nitrogen coolant that will be able to bring the background noise to an acceptable minimum level. This will enable better qualitative and quantitative measurements of ablation species. Also suggested are the use of X-ray Microtomography for spatial microstructural studies, and infrared pyrometers and thermo-cameras to adequately monitor the surface temperature profiles across experimental samples.

VIII. Future Work

Part of the future work will be to use the measurements from present technology to compare with already measured/documented beta-prime for graphite ablation of other researchers, thus creating a good benchmark for verifying the new experimental technique contained herein. There was no evidence of any mass loss on the backside of the graphite sample (where it was heated). This could be as a result of the inert gas (argon) which suppressed the oxygen concentration at the backside [Park 1976] but further investigation needs to be carried out. Also, some aerospace research experts have argued that the application of the new technology to other types of highly porous ablative materials might seem problematic. In the case of graphite, which is regarded as a high thermally conductive material where the heat rapidly distributes over the test sample [Scala and Gilbert 1965], this might not be the case for carbon-phenolics like PICA [Metzger at al 1967], leading to pyrolysis and deformation of the material at the backside [Trick and Saliba 1995] as compared to the frontside within the short time frame. If this happens, the backside would be highly pyrolyzed and ablated [Wong et al. 2015]. Details from oxidation and reaction kinetics [Rosner and Allendorf 1965] from other high enthalpy facilities also need to be compared with the present work.Most newly developed ablators consist of a very porous carbon fibre matrix [Torres-Herrador at al 2021], infiltrated with phenolic resin as decomposing filler (PICA, ASTERM, ZURAM) [Koo and Wang 2022], which have been heavily studied over the past decade [Torres-Herradoret al. 2020]. Such carbon preforms like CBCF 18-2000 can also serve as an ideal candidate for the basic studies of carbon ablation related to thermal heatshields. In order to obtain further thermal distribution parameters that are associated with the new technology, further work needs to be carried out to assess the Biot number using different thicknesses across a range of ablation materials samples. Depending on the wind tunnel facility used, further dimensionless quantities like Re, Ma, Ch, and Da need to be fully characterised with the surface chemistry in order to replicate a specific re-entry trajectory point.

These future works will allow good documentation of any potential drawback(s) that might be associated with the new technology as compared to other facilities.

Using graphite sample, this novel invention has been able to accurately replicate the planetary re-entry surface temperatures and any associated hypersonic flow characteristics within the boundary layer. This patented technological innovation is a new dimension of aerothermodynamics research, fully developed for series of ablation tests in any reliable aerospace laboratory anywhere in the world. To make sure that this innovative technology reaches as many people as possible, the author and his entire research team will continue to be responsible for any unforeseen technical issues. This will help in mutual collaboration by actively supporting aerospace research individuals, centres, agencies, institutions, universities, academia and researchers, thus enabling more re-entry experiments at a minimum cost, without compromising the quality of research outcome. The ongoing continuous improvement of the NGEM will address the structural integrity, by incorporating water cooling system for better survivability in thermally aggressive environments; but again, this depends on the specific need/application. Unlike the present experimental model, the next generation model is simply sophisticated and automated with some C++ programming in the brainbox that made the latest invention to be more versatile for complex re-entry experiments. However, this information remains classified and will barely be made available to the public.

The two major improvements associated the NGEM over the model used in the present work are: (1) a reduction of the heat losses via conduction on the heatshield sample by incorporating a thermal barrier between the test sample and the backshell, and (2) the incorporation of six degrees of freedom (6DOF) to account for variable angle of attacks for better manoeuvrability during re-entry, descent and landing [Iyinomen 2022a]. These increased operational capabilities are the milestone of the NGEM that have never been attempted for any re-entry aerothermodynamics studies elsewhere [Iyinomen 2022a]. The fact that the NGEM is able to attain surface temperatures in excess of 3000 K, will encourage the use of spectroscopic measurements of ablation species and spatial microstructural studies using X-ray Microtomography. Infrared pyrometers and thermo-cameras are also needed to adequately monitor the surface temperature profiles across experimental samples. The aim of the NGEM is to improve the operational capabilities of the new plasma preheating technology by readdressing the thermal and aerodynamic performances of the present work, and the author is doing everything possible to make it happen. These modifications enable the NGEM to be smarter and more practically replicates real-flight vehicles as shown in Figures 29 and 30.

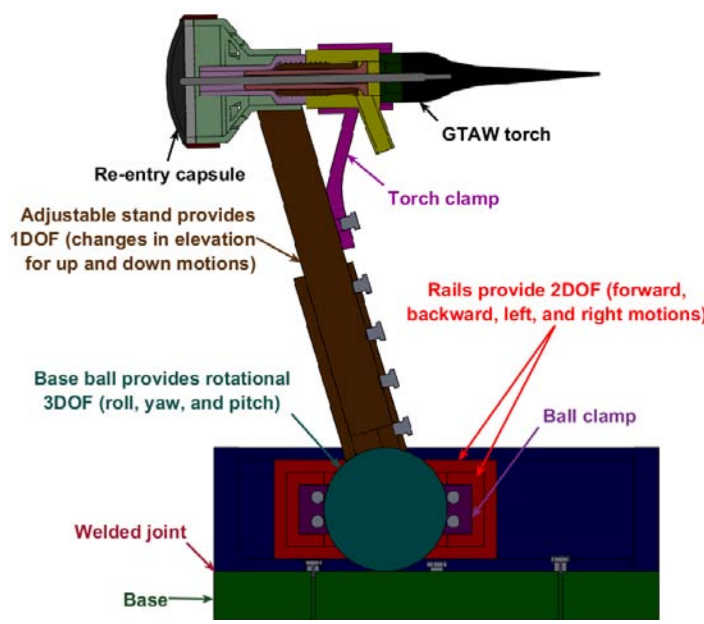

Figure 29: Simplified sectional view showing the improved operational capabilities of the NGEM using an experimental geometric sample of Orion heatshield of 2 mm thickness [Iyinomen 2022a].

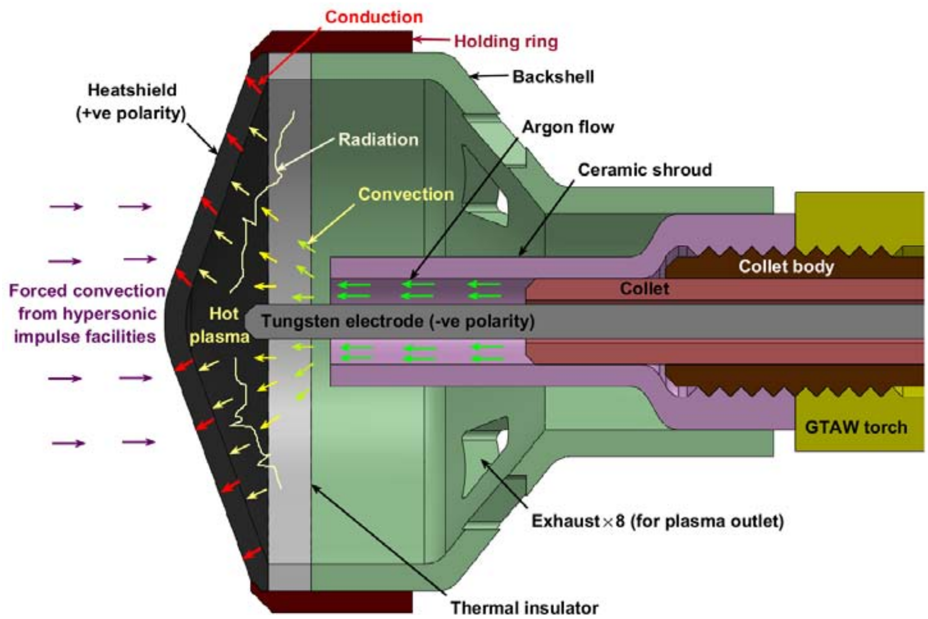

Figure 30: Thermophysics and heat transfer in probe model for future experimental tests using an experimental geometric sample of Stardust heatshield of 2 mm thickness [Iyinomen 2022a].

Table 2: Materials selection for NGEM components and parts to be used for future ablation experiments. The criteria/rationale for the justification of materials selection are contained elsewhere [Iyinomen 2022a].

Component/feature	Present model	NGEM	Scientific relevance
Geometry	Simplified	Advanced	Better operational performance.
Stand	Rigid/fixed	Adjustable	Allows flexibility in elevations
6DOF	Absent	Present	Better aerodynamic manoeuvrability
Backshell	Mild steel	Stainless steel	Housing and support
Backshell thickness	5.0 mm	2.5mm	Reduced mass and heat-sink effects
Holding ring	Mild steel	TiC	Higher thermal capability over steel
Thermal barrier system	Absent	Present	Reduced conduction losses
Ceramic shroud	96% alumina	Zirconia	Higher thermal capability over 96% alumina
GTAW torch	Detached	Attached	Thermal optimisation over detached features

IX. Conclusions

The weighing method concluded that the average mass loss rate was 0.020 g/s for the flow period during sixteen heated-with-flow runs, 0.001 g/s for flow-only and 0.00055 g/s on average for heated-only. Flow-only mass loss rate is about 4.9 % of the average mass loss rate during the flow of heated-with-flow runs. An average mass loss rate during the heated-only runs (and therefore during the heating phase of a heated-with-flow run) is not particularly useful to report. The Scanning Electron Microscope (SEM), the Laser beam visualisations, micrometre gauge, and measurements using the measuring arm were used to identify the shape changes due to ablation. Changing surface characteristics resulting from flow were identified by using the Scanning Electron Microscope (SEM). The results from SEM and laser sheet experiments reveal continuous thickness reduction with increasing number of runs. The major area of interest is using plasma to preheat probe models that can be used for ablation studies in cold-flow hypersonic wind tunnels. The plasma generation is a new technique that generated the needed heat flux for the surface temperature characterisation without using any arc jet or plasmatron facilities. This technique aims to produce a newer and better method of aerothermodynamic tests for investigating ablation samples of re-entry probes in expansion tubes. The probe used was very similar to the European Standard Probe with a stagnation temperature of about 2500 K. This intellectual property is not elsewhere classified and will significantly aid aerothermodynamics of re-entry studies of the entire universe, and provides extremely useful contributions to improving aeroheating test reliability in hypersonic impulse facilities around the world.

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Professional English - Graduates of Ukrainian Universities

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Resume- The Ministry of Education and Science of Ukraine (MES) has set the task of Europeanization of higher education in Ukraine. An important element in this matter should be the ability to communicate in English with colleagues from abroad on professional issues. The article provides suggestions for solving this problem.

Keywords: europeanization of higher education, professional english, measures to solve the problem.

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I. Formulation of the Problem

Today Ukraine is not included in the top rankings of the best universities in the world. Why? One of the reasons is our ignorance of the English language. More than 90% of scientific information in the world is published in English, and former Deputy Head of the Presidential Administration Poroshenko Dmytro Shymkiv reminded that "In all countries that have taken a course to actively study English, there has been economic growth." Back in 2010, it was said: "For Ukraine to finally appear in this ranking, it is necessary to introduce a state program of English language study by our scientists" [1]. And who are the scientists? These are yesterday's students. That's where we need to start. As for world experience, for Western European students it is now the norm to know two foreign languages and it is not uncommon to know three.

a) *The Present*

How the issue of professional foreign languages is resolved in some higher education institutions (HEIs) of Ukraine. From the prospectus of the Dnieper State Academy of Civil Engineering and Architecture (DSACEA) [2]: On the way to integration into the European educational space. Modern educational technologies of the Dnieper State Academy of Civil Engineering and Architecture - Prestigious specialty + 2 foreign languages + Personal computer skills = Components of success in life and career. DSACEA Information Collection [3]: "Today it is obvious that scientific and technical information can be correctly perceived or, if necessary, translated by specialists in a particular field of science and technology, rather than language specialists." "Such thinking suggests strengthening the training of engineers specializing in foreign languages in polytechnics in Ukraine." At the National Aviation University (NAU), Kyiv, for more than 20 years today there are 22 specialties, 312 highly qualified teachers - teaching in English. Something is being done at the Kyiv National University of Construction and Architecture (KNUCA), at the Department of Water Supply and Sewerage. There are a number of other HEIs where this issue is given due attention. But these are rather exceptions. Today, the study of foreign languages in the HEIs is the translation of texts from a foreign language into a native language, for example: "Professionally oriented text." Not quite specifically. According to Omelyan Vyshnevsky, a professor at Drohobych State Pedagogical University [4], "translation from a foreign language into a native language is generally aimed at improving knowledge of one's native language, not a foreign language." Quite right opinion. When you ask students in high school questions: What can you say in English about your speciality?, you usually hear the answer: so-so or a little. Much less often you can hear something in fact. But there can be no claims against students, they are simply not taught that. H

b) *Recent Documents of the MES of Ukraine*

Current “Law on Higher Education” [5]: “In order to create conditions for international academic mobility, a higher education institution has the right to decide to teach one or more disciplines in English and / or other foreign languages, while providing higher education knowledge to the relevant discipline in the state language”. Not very specific, not required. In the summer of 2019, a number of documents of the MES of Ukraine will be published, which raise questions about the English language in higher education institutions and pay special attention to the introduction of English in the educational process of Ukrainian HEIs. Thus, the MES "created the Concept of English Development in Universities" [6], which states that "the economic development of countries is highly dependent on the knowledge of English by citizens." "And today, when we look at Ukraine, of the 32 non-English speaking countries in Europe, we rank 28th out of 32 in terms of English language proficiency." The note "How to improve the level of English language skills" [7] states that "the level of English language skills in students does not increase, but decreases during study." The Conceptual Principles of State Policy for the Development of the English Language [8] especially emphasizes: “Teaching

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professional disciplines in English as a component of the Ukrainian-language program (English as Medium of Instruction for Ukrainians - EMI)," " language for foreign students (English as Medium of Instruction for Foreigners - EMI-f)"; "Improve the support of EMI teachers in institutions, including English language training"; "75 percent of high school graduates will speak at least two foreign languages," and "by 2025, graduates of all levels must speak English at least B2." The task is "professional knowledge of English", "teaching professional disciplines in English", "providing education (individual disciplines) in a foreign language". Very important materials. But there is no categoricalness, obligatoryness, time goes by, and there is almost nothing in common between the instructions of the MES and the educational process in the HEIs; or as in the paraphrase of Colonel Skalozub from the comedy O. Griboyedova "Woe from the mind": "Huge distance." And I would like to ask the following question - are the ministerial materials on the English language, which can be found on the Internet, mandatory, or are they just opinions and nothing more, because - "Recommendations". Not required. Quite an uncertain position. Given the latest guidelines of the MES in English, here are the opinions and suggestions of the author in this regard. The educational process should be organized in such a way that graduates of the HEIs who study in the Ukrainian language would have basic, basic knowledge of their specialty in professional English. What, in the author's opinion, should be done for this?

c) The Work of Foreign Language Departments

Foreign language departments need to significantly restructure their work, taking as a basis, for example. Department of Foreign Languages of NAU, on the example of language training in the specialty "Industrial and Civil Engineering" (one of many). Specifically, what topics are considered by the Department of Foreign Languages - building materials: stone, brick, cement, etc.; structural elements of buildings, types of foundations, etc.; engineering networks and communications. And so on all specialties, under the guidance of profiling, graduating departments. Mandatory external independent survey (EIS) in a foreign language when entering the HEIs. This will encourage students to take a more responsible attitude towards learning foreign languages at school. In addition, it is necessary to get acquainted in detail with the experience of DSACEA in learning a second foreign language, secondary, German or French, put this issue on the agenda, given that 75% of school leavers will learn two foreign languages [8].

d) The Work of General Technical Departments

In the study of general technical disciplines to give in English translation the terminology that will be needed in the study of the specialty. For example, the Department of Higher Mathematics. Students must master in English all the mathematical apparatus that will be required in the relevant engineering disciplines; ie: +, -. x,:, roots, degrees, etc. And so on in all other disciplines, for example, resistance of materials, building mechanics, hydraulics, etc.

e) The Work of Profiling, Graduating Departments

Lectures, practical classes, laboratory work. Each classroom, homework, oral answers, term papers, laboratory work, dissertations - the main, key points, sections, diagrams, drawings, in a concise, final form, with translation in English. The same applies to practice reports. All inscriptions in the HEIs, namely: department, dean's office, laboratory, rector, etc. - should be duplicated in English. According to the author, technical English is relatively simple, uncomplicated, informative, simple grammatical forms are used.

II. Methodical Literature

In the methodological literature after each section (subsection) - to give the Ukrainian - English dictionary of key words, basic terms, technological processes - on the topic. Names of each section, figure, diagram, chart, graph - with translation. It is expedient to prepare Ukrainian-English dictionaries for each specialty, according to the curriculum. It is desirable that each leading lecturer in his discipline summed up, generalized and repeats the acquired knowledge, such a thesis - in English, such a thesis will be made by each teacher in his discipline. Such organization of the educational process will contribute to the training of specialists of modern international level. It is clear that in the beginning it will be difficult. But we need to start someday.

III. Organizational Issues

At each department, at each faculty, in the rector's office - to hold relevant meetings, listen to all opinions, proposals, ideas, discuss, make decisions - and for work. Appoint those responsible for professional English at each department, at each faculty. To coordinate and lead this work is to instruct the Vice-Rector for Academic Affairs. And here, perhaps, the most difficult question - hours. But here is a direct indication [8]: § 4.1.3. English for Students "English courses must be compulsory in each year of the program. At least 10% of the total number of hours/credits for students must be allocated to English language courses. To provide additional English language classes, departments must use 25% of the credits allocated to elective courses and devote them to learning English."

IV. Masters

Finally, the final stage of higher education - masters. When entering the master's program in all

specialties, take not the national unified entrance exam (UEE) in English, as in the instructions of the MES [9], in this case the position of the MES is decisive and categorical, but - professional. This must be decided either by the MES or by the administration within the university autonomy. And no other way. Because taking an UEE from a foreign without the necessary knowledge after the bachelor's degree is a completely ill-considered, harmful, premature decision; it can close the path to a master's degree for many bachelors, it's like releasing a newcomer against a professional. Defense of a master's thesis with a mandatory translation of the main provisions - in English. And the last thing: no one has canceled the role of the leading person. Their role is crucial. These are the head of the department, dean, vice-rector, rector. Point. For many years, the author, by asking these questions to the administration, tried to somehow solve this problem. The result was, but minimal, earned the right to teach by professional English. There is a change in the leadership of the department and the author does not receive a study load. The article with the above proposals is provided to the head of the department, dean, first vice-rector and rector. No answers. Although - there was something. Deputy Dean: so we have all the hours painted, 1st Vice-Rector: so, from some discipline should be removed hours? Here German winged words are appropriate: “Keine Antwort ist eine antwort” - No answer is an answer. No comment. The story of O. Solzhenitsyn comes to mind - "A calf with an oak tree", A. Chekhov - "poor relative", O. Tolstoy - "Walking through torment". Two quotes from Latin: “Non progredi est regredi”- Do not go forward means go back; “Tempora mutantur, et nos mutamur in illis” – Hour change, and we change with them. Still Petro 1 saying: Do not adhere to the statute, like a blind of wall, for the orders are written there, but there are no times and cases. Imagine such a fantastic picture: Gathered 3 computer genius - Bill Gates, Steve Jobs, Mark Zuckerberg and decided to offer their ideas and achievements to humanity. They go to the nearest university of communications and begin to acquaint the management with the developments. And they are told that everything is planned, painted and there are no opportunities for your proposals. Could this be? And never! No way. If that happened, God forbid, there would be no modern computers, no cell phones, no modern communications, calculations would still be done with a logarithmic ruler, and a pencil would be used instead of computer graphics. Well, progress cannot be stopped, and mastering professional English for a modern specialist is one of the elements of progress. It is a pity that sometimes, trying to keep up with the times, you do not keep up with your administration. The MES program in English will require teachers to update their knowledge of English, which they taught 10, 20, 30, 40 or more years ago. It will be quite difficult. And to learn the basic terminology, key phrases - it will be much easier - and you can immediately start using the proposed scheme of classes.

V. Conclusions

Immediately put on the agenda the solution of the following issues:

1. The MES is pursuing a more vigorous policy on professional English in the HEIs.
2. Ensure radical and sectoral changes in the teaching of foreign languages at universities.
3. All teachers of specialized departments in their work give key terms in English.
4. To return to the practice of testing applicants for a master's degree in professional English on the platform of HEIs education.
5. Put on the agenda, if possible, the issue of learning a second foreign language by students of technical specialties (experience DSACEA).
6. Instructions of the MES of Ukraine [6], [7], [8] on the English language, after appropriate training, begin to implement in the educational process.

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Global Research of Innovation Green Concepts of New Hybrid Electric Integral Modul Aircrft and Solar Disc Airship

By Ponyaev L. P., Kuprikov M. Yu., Kuprikov N. M. & Domjan R.

Abstract- Actually New Innovation Green Concepts for future World Ecology Air Transportation Technologies will be focusing to new Optimal Geometry Structures as the complex Integral Disc-Wing Adaptive Transforming Frames for any Passenger Hybrid Electrical Aircraft and Solar Disc Airship with more Efficiency Active Vortex Energy Systems. The new International R&D European Programs to the Aircraft Vision'2035/40 are consist the innovation Design Science MAI Results and Patents for participation during 2020/23 to joint EC Research Consortium IMOTHEP and FUTPRINT50 of Hybrid Electrical Power of the Regional Aircraft for the Low Toxic and Low Noise Air Transport Operation Worldwide as recovery initiatives after COVID-19 Destroy pressure to the International Airlines and Consortiums new priority Low Cost Efficiency and Commercial Strategy.

Keywords: aircraft; airship; disc; electrical; solar.

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GLOBALRESEARCHOFINNOVATIONGREENCONCEPTSOFNEWHYBRIDELECTRICINTEGRALMODULAIRCRFTANDSOLARDISCAIRSHIP

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Innovation Hybrid Electric Air Transport Projection

Ponyaev L. P. [α], Kuprikov M. Yu. [σ], Kuprikov N. M. [ρ] & Domjan R. [ω]

Abstract- Actually New Innovation Green Concepts for future World Ecology Air Transportation Technologies will be focusing to new Optimal Geometry Structures as the complex Integral Disc-Wing Adaptive Transforming Frames for any Passenger Hybrid Electrical Aircraft and Solar Disc Airship with more Efficiency Active Vortex Energy Systems. The new International R&D European Programs to the Aircraft Vision'2035/40 are consist the innovation Design Science MAI Results and Patents for participation during 2020/23 to joint EC Research Consortium IMOTHEP and FUTPRINT50 of Hybrid Electrical Power of the Regional Aircraft for the Low Toxic and Low Noise Air Transport Operation Worldwide as recovery initiatives after COVID-19 Destroy pressure to the International Airlines and Consortiums new priority Low Cost Efficiency and Commercial Strategy.

Keywords: aircraft; airship; disc; electrical; solar.

I. Introduction

The Future Strategy of Modern Airlines after the Global influence of negative COVID deformation to Safe Health Air Transportation will be focus to the New Green Technologies. The New Vision to more Electrical Aircraft & Airship are forwarding as more priority to use low toxic/noise Hybrid Energy Electric Powers and Adapting low noise Eco Systems.

The Civil Aviation Science Research Programs in Europe and Worldwide have the goals to find the Optimal new Integrate Aerodynamic Geometry and Shape Frames of Grows of any International Long Range for Economy Efficiency of Small Regional and Large Inter Continental Vehicles.

Therefore new Aircraft & Airship Projects for International Air Transportation will be priority focusing as to the more Ecology Low Toxic Engines as to Hybrid Electrical Power System for decrease Noise/Sound Level in Sky and near Airports areas. The main High Tech targets are minimizing influence of the future 'Renovation' Airline Operations to World Nature and Protection of our Ecosystem. The famous Aircraft Conceptions and Dialectical Contradiction between the constantly improving new types of future Aircraft Design Methods and the continuously aging Big Hub Airport Infrastructure arose from the very first days of the advent of Aviation and it is of a fundamental Air Industry, Airlines Facilitation and infrastructure complex (7, 8, 9, 10, 19).

The main CAD/CAM/CAE and Life Circle High Tech are request concrete International R&D Design Strategy for a certain class of Aircraft, one can distinguish a group of limitations that are conceptual in Nature and have a priority influence on the generating process of evolutional Aircraft Conceptual Design (ACD).

Integrate Disk-Wing Concepts are the best aerodynamic stability on high angle of attack and more safety efficiency for Aircraft Structure. Digital Complex Criteria Analysis of the find General Optimal Construction of the Large Hybrid Electrical Aircraft and Airship for decrease of Sound &Noise Pressure Level inside and outside the Cabin and Passenger Saloon are very actually today for Globally High Tech Ecology Program.

The Analysis of Aviation Practice of any Companies confirm that the Digital AI Methods of the Large Disc-Wing Aircraft layout from the virtual mass center is given, which allows us to obtain the Aircraft layout from the actual resource conditions of Infrastructural Top Efficiency Constraints in the terminal configurations of the Modern Air Transportation Infrastructure and International ICAO & IATA Regulation.

II. New Green Innovation Geometry and Digital Complex Method

The Universal Digital Method is proposed for the Synthesis of New Innovation Solutions for Large Hybrid Aircraft (LHA) with Integrate Disc-Wing Body E-Aircraft conceptions of Passenger High Comfort compartment and may be use to any Disc Shaped Rigid-Elastic Solar E-Airship Projections future.

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A significant impact on the satisfaction of Infrastructure Requirements is provided by structural and layout solutions. The ACD taking into account the infrastructure requirements, will allow them to be taken into account in the early Stages of Aircraft Design (2, 5, 6). The solution of the problem of the ACD as a problem of mathematical Digital Modeling Software (12, 13) by CATIA5 of CAD/M/E System does not always lead to success because of the considerable dimensionality of the vector of constructive parameters X*, the complexity of the set of constraints U, as well as the large time required to compute the objective Optimal Function Vector. The main Design Decomposition Methods of the vector dynamic system of target functions, project parameters and constraints is very important. This circumstance is connected with the fact that the layout of the Aircraft is the result of Compromise Solution of Digital Design tasks, which is typical for new R&D Optimal Versions and Patenting ACD of the Future Ecology Regional and Cross Continental Air Transportation.

The results in LAB MAI as the Geometrical representation of the LHA concepts with the large Passenger or Cargo capacity made with a Drop-Shaped Body with view of the new Flying-V Lift Fuselage by TU Delft R&D in the Aerodynamic balancing Geometry of Wing Body Scheme is given (14). The Swiss SOLARSTRATOS High Altitude Aircraft as Natural Arctic Low Zero Temperature Long Time conditions for New Russian-Canadian TRANSPOLAR Airlines and test result by Russian Test Flights by TRANSAERO Airlines are using to correct Big Data Stress Analysis of any Geometry Constructions with Damping E-Active Systems for Calculation Software Projections results and Technology recommendation.

The Engineering Design Results may be use as recommendations to new Geometry Optimal Projections of the Integral Disc-Wing Plane LHA and Lighter-then-Air (LTA) Vehicles as Thermoplane MAI (17) with nano film soft cover of the Swiss-China Solar Electro Accumulators Systems will be more innovation projections for E-Air Transport Solar Battery Security with reduce Noise & Toxic Level. The advantages of Digital E-Aircrafts and E-Airship projects according to the Flying Wing Scheme in relation to other schemes rise with the increase in the Dimension and Optimal Weight of the Aircraft. So, the greater value of the target load and the Air Transport Flight range is the better application of this new Integrate Wing Drop Body Aircraft and Disc Airship Schemes.

III. Methods and Features of the Layout Limiting Space for Minimize Sound and Toxic Level

Complex Analysis of any Optimal Aircraft Structure of the New Modern Aircraft are basing on the main Complex Minimax Data. The identification of the layout Limiting Space and Noise Level around/inside Large Aircraft (13) as the decomposition according to the characteristic features and the identification of a critical factor for the Long-Haul Aircraft (LHA) innovation Design projects as see at Figure 1, 2 and 3 (3, 4, 15, 16):

- Rhombus Wing low vibration frame with Ellipse Body concept;
- Bi Body low vibration structure concept;
- Delta Wing Body E-Aircraft concept;
- Fly Multi Body Airship as 3-Di T-117 projection concept.

Figure 1: New 4 Innovation Green Versions of LHA Aircraft and Airship

If we consider the whole issue, from the point of view of the 3D Volume-Weight-Drag Configuration, the optimal solution will be an Aircraft for which the external contour was obtained as a result of positioning of individual aggregates taking into account the criticality of the layout both with respect to the three axes coordinates and in three planes, and for any arbitrary radius-vector, starting from the center of mass of the Aircraft and quasi center of Noise/Sound area of Engines.

Figure 2: Any 6 Innovation Concepts of Disc-Rhombus Wing, Delta Bodies and 'Canard' Concepts of LHA Aircraft

A characteristic feature of the layout with "hard" dimensional constraints is the possibility of carrying out spatial coupling of many units in the first iteration, which allows us to build layout from a certain virtual center. It is convenient to choose the origin of the associated coordinate system, which coincides with the real center of mass of the Aircraft. Therefore, the layout problem is reduced to the location and interconnection of units in the layout space due to infrastructure constraints from the condition of bringing the real center of mass (RCM) to the virtual mass center (VMC) and providing characteristic features for Aircraft Design LAB MAI SW, as show on Figure 4, that satisfy both infrastructure requirements and others, for example, Aerodynamic efficiency (2, 12).

Figure 3: Vision of 4 Concepts with Disc, Delta and Elliptical Bodies of LHA Aircraft

In Figure 4 shows a three-dimensional image of the layout inside 3D Airspace for the LHA, obtained from the results of the structural-parametric analysis of Airport terminal configurations, the Comp-Digital Method of Aircraft Design parking and taking into account the Aircraft height limitations from the condition of PAX ability to the parking shelter Gate (23 m). Of course, in this case, the issues of antennas and equipment layout at the top of the surface are taken into account.

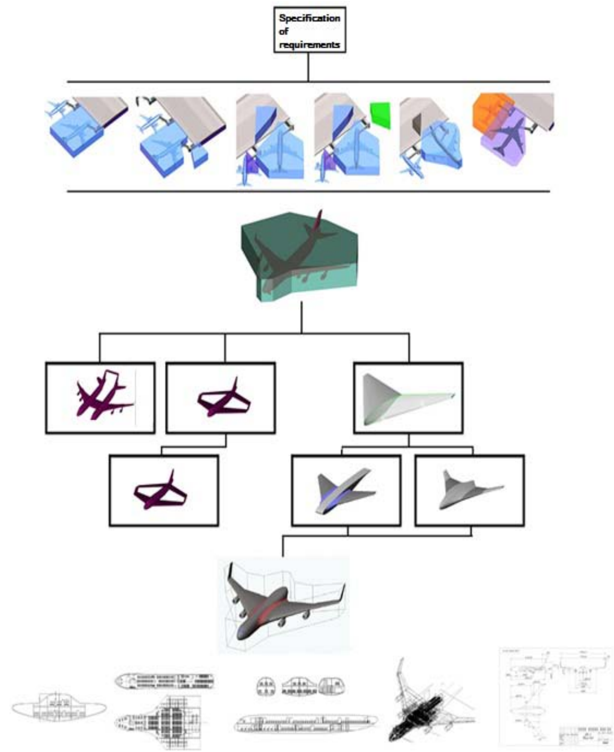

Figure 4: Influence of infrastructure restrictions on the any Geometric Shape of the Long-Haul Aircraft Scheme

The second level shows conditionally the range of permissible placement of passenger decks of the LHA. Their layout is determined by the dimensioning height (3.8 m), the length (20-25 m, and in prospect – 40-50 m) and the Limiting deviation angles in the vertical plane (10%) of the terminal slot hand-bridges.

We make a comparative analysis of the Aircraft as the basis of the Flying Wing Scheme, Bi Fuselage and the Normal Scheme. As a base, the passenger compartment of the LHA (comp-digital first iteration) was adopted. The second comp-digital iteration is the wing and fuselage. Third iteration is the wing, fuselage and tail. And the fourth comp-digital iteration is the whole composition of the aircraft aggregates, which corresponds to the complete washable surface (taking into account the engine nacelles).

And so, the specific Volume per passenger (average in all cabins) was 2.485 m^3, which is 1.17 times worse than for the base Aircraft (as Normal Aerodynamic Scheme), but its 1.30 times better than for the Aircraft in the Lifting Fuselage Scheme, and 2% better than for the Aircraft with a Triplane Scheme with an articulated wing.

The developed Method of the Aircraft layout from the layout inside Airspace made it possible to obtain the Aircraft layout that meets all infrastructure requirements, with take-off mass of 30-40 tons less than that of the Prototypes.

IV. The Dimension of Integral Long-Haul Aircraft and Weight/Drag Reduction

Within the framework of the Research work at the Design LAB MAI, a Comp-Digital Structural-parametric Analysis of alternative layouts of the Long-Haul Aircraft with large passenger capacity was carried out. The analysis shows the advantages of the layout carried out according to the above Method (LHA-5 Flying Wing Scheme) in relation to other non-traditional Schemes and a minor loss to the base Aircraft. At the third level, the Geometric shape of the layout inside Airspace is revealed as a result of the structural-parametric analysis of the LHA infrastructure constraints. Further, there are many ways again, but we must take one of the World Patenting hypotheses:

- Circumferential fuselage,
- Twin-fuselage scheme,
- Flying wing
- Drop-shaped fuselage, etc.

Some alternatives are graphically represented at the fourth level as results of R&D on the MAI Aircraft Engineering Graphic & Comp-Modelling Department may be introduce of the Figure 4. But let's analyze it. At the first stage, we determine the required volume for placing one passenger.

Traditionally, the layout of the passenger compartment of the LHA is realized from the cross section, which is replicated in length as a model, taking into account the nuances of kitchens, wardrobes, toilets, etc. However, the excess pressure causes a circular cross section.

$$\mathbf{V_1 = SH + V_{diff.}} = \mathbf{0}.93 * 2.1 = 1.953\text{m}^3$$

Figure 5: Change of Geometric shapes of the Cylindrical Shaped fuselage from excess pressure with any Integrate Wing Body and Hybrid E-Power Innovation

The fuselage, made in a cylindrical shape and having a circular cross-section, has a minimal mass. On the Figure 5 show a change in the Geometric shapes of the cross section of the cylindrical-shaped fuselage from the influence of excess pressure is given. In order for the section to keep the shape in the beam fuselage structure in the frame, in addition to the longitudinal force elements, the formers are installed, as transverse power elements.

Choosing a variant of the E-Aircraft concept with an Integral Fuselage-Wing and distributed along the trailing edge of Multi Small Electric Fans can create a synergistic effect to increase the resulting Super Circulation and accordingly the carrying capacity of the Aircraft like Jet Blowing Systems.

At the second stage, the number of passengers is taken from the specification of requirements, which multiplied by the volume of one passenger allows us to determine the Minimum required Volume of the Aircraft. If the volume is known, then the minimum area of the washable surface has a body equivalent to the Sphere, see Figure 6.

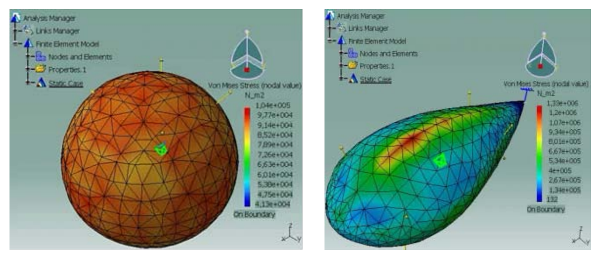

Figure 6: A Sphere and Integral Pressure Schemes Vision equivalent to the fuselage 3D Volume of the long-haul Aircraft

Excess Optimal pressure of Weight and Sound Loads, which suppresses the shell from the inside, gives a uniform distribution of the stress-strain state. However, for a flight in the Atmosphere, the Spherical shape is not suitable. The Geometric shape for subsonic flight should be stretched and be more like an Aerodynamic profile.

Performing the Geometric operations of affine extension-compression with an equivalent Sphere in 3D Volume, we obtain the Disk, see Figure 6. The structural-parametric analysis of the stress-strain state shows a pronounced anomalous zone. For its compensation, a power element connecting the two poles is needed.

V. The Perspective Disc Shaped Geometry for Minimum Structure Vibration Loads

The Aerodynamics of Discs Shaped of Dirigible was use for Innovation Projection in MAI. It's the MAI Light-then-Air (LTA) Disc Shaped THERMOPLANE (Figure 7) is the unique and patented Project supported by President of Russia or other version as Ellipse Body ATLANT Projects may be MAI self new initiative with the Laminar Flow Control and Solar Battery Nano Film Upper Surface System as used now and show on Figure 8 for more Electrical Skyships PAX & Cargo Transportation for Flight and Rescue Operation with complete the LHA as High Ecology Air Transport Aircraft & Airship conceptions to Future Mobility Development (17, 18).

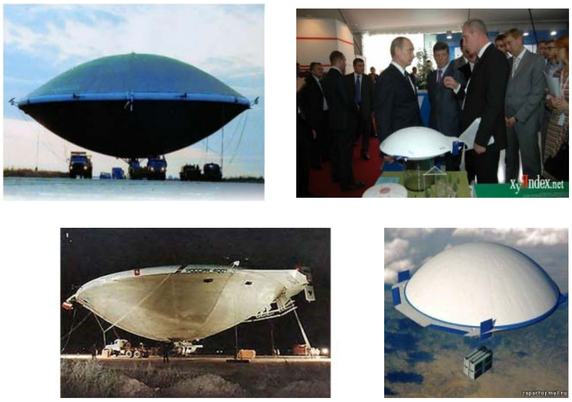

Figure 7: The patented Disc Shaped LTA THERMOPLANE ALA-40 Project by MAI

The LTA are oriented to a long time flight, so a high priority in the formation of the washable surface is a High Aerodynamic Quality. And it is the higher, the lower the resistance and the greater the bearing capacity is. The Drop Shape of the bearing fuselage and the washable surface of the LHA Aircraft made according to the more efficiency Integral Formation with minimum Vibration and Noise/Sound Interferences as minimum influence to the World Ecology.

Figure 8: The Solar Batteries Small Swiss Aircraft and Thales Alenia Airship

Inside the disk-shaped LTA, you can easily form at least three vertical confusers with wide pipes on the upper surface and narrowing confusers at the outlet – a rotary nozzle system with control of the thrust vector from the vertical to the horizontal component of the LTA cruising thrust, which will provide a significant recharge of the power generator systems through the turbine and built-in power storage, reducing the level of vibration and noise inside and outside the LTA.

Super Vortex or Tornado Turbo Energy Technologies (Tornado Like Jet Technologies - TLJT), allow you to increase the power of the generated flow, accelerate the flow of solid medium flowing in and out of the nozzle, concentrate and significantly increase the speed, almost without additional hydraulic losses between the streamlined surfaces and the environment involved in the vortex movement. When providing the necessary and sufficient conditions for self-organization of TLJ, determined from the analysis of exact solutions, such jets are embedded in the environment of origin, locally changing its dynamic state (11).

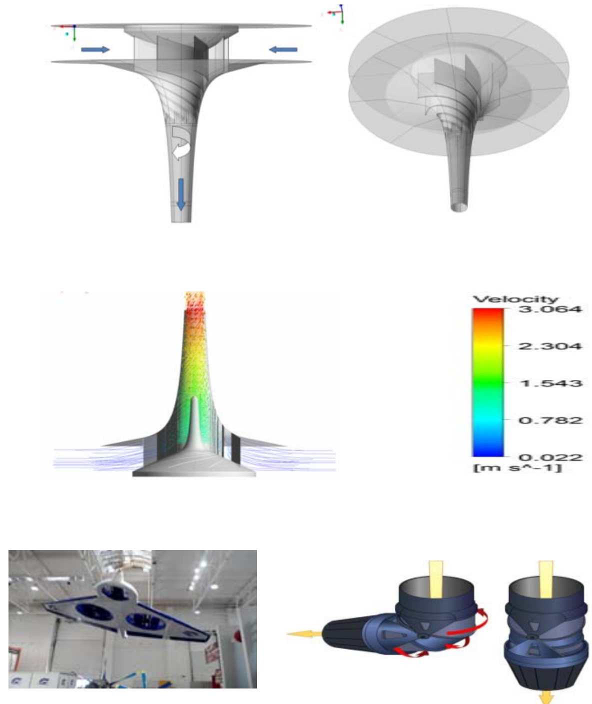

Figure 9: The Super Vortex E-Generators for Disc Airship E-Thermoplane MAI

The formed swirling current carries out the suction of the medium from the surrounding space the flow power of which is N_{in} the sucked flow moving along the confuser, accelerates, concentrating the total power in the formed Tornado-like Flow:

$$N_{out}/\ N_{in} = k \cdot R_{out} \cdot W^3/\ H_{in} \cdot W_0^{\ 3}$$

where W_0 is the flow rate of air flowing into the confuser, W is the flow rate of air flowing from the nozzle, k – coefficient determined by the geometry of the constrictors, the values H_{in} and R_{out} are regulated by the geometry of the constrictors and the formation of Tornado-like pressure of a given flow to ensure increased flight speed LTA at low source power and low cost of electricity.

The Romanian ADIFO project, named as an omnidirectional flying drone (1) is made in the form of a Disk and its designers have quite reasonable explanations. It is similar to the Vought V-173 (USA) Disc plane (20). The working prototype created for testing has a diameter of 1.2 meters and is equipped with a Hybrid Electro-reactive Propulsion system.

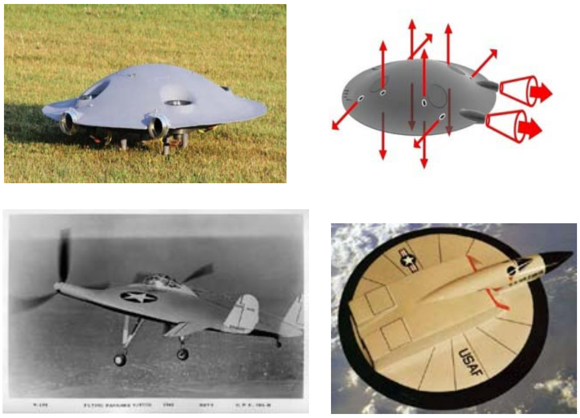

Figure 10: The Disc ADIFO Model Drone with Active Vectors Control Shema and Disc Vought V-173 Aircraft

The ADIFO "Flying Saucer" Shape was specifically designed to give the vehicle certain characteristics: - the device is unique in that it can move in any direction with the same aerodynamic characteristics and can fly just as well in subsonic or supersonic modes, which changes the current flight paradigm. The shape of the "Saucer" in contrast to the usual wing of the Airplanes provides maximum maneuverability. The device is similar to a Drone in its ability to take off vertically and "hover" in the air using Four Electric Turbo Fans.

According LHA optimal concepts analysis the main variants Body Wing Shema of the Internal layout of passenger cabins are obtained for the case of transportation of 616 passengers in a three-class layout of cabins for a distance of 13 700 km. At the same time, the degeneration of the Flying Wing Scheme is clearly visible. In this dimension a developed fuselage part already appears. This fact is connected with the peculiarities of the layout of passenger cabins. The need to provide the specified volumes, height and width of passenger compartments requires an increase in the Internal Volumes of the Flying Wing. For example, the increase in overall heights in the central part of the wing is due to the provision of a Minimum height of the Passengers Cabin Saloon and decrease inside/outside the 3D Volume of Noise Engines Level. Therefore, in the central part of the wing the chords are enlarged to provide the necessary overall heights.

VI. Conclusion

The advantages of aircrafts designed according to the Flying Wing Scheme in relation to other schemes rise with the increase in the Dimension of the Aircraft. So, the greater value of the target load and the flight range is the better application of this new Integrate Aircraft Scheme. In comparison with the base Aircraft of a Normal Aerodynamic Scheme, the Noise Level decrease up to 84%, and in comparison with a Tree Plane Scheme with an articulated wing - 94% from the Classical Version of Aircraft and Cigar Shaped Airship. The Computer Digital Structural & Parametric Analysis of the influence of infrastructural requirements on the 3Dimention Complex Synthesis of Long-Haul Aircraft and Solar Disc Shaped Airship Projection to use also More Electrical Hybrid Power Ecology Systems. The new Body Plane LHA and Lighter-then-Air (LTA) Vehicles with cover of Nano Film Solar Electro Systems will be more innovation projections for Worldwide Security Air Transportation with reduce CO_2 Toxic Pollution and Noise level.

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Peculiarities of UAV Construction for Flights at High Altitudes

By V. Kharchenko, O. Onyshchenko & H. Bahmanfar
National Aviation University

Abstract- A mathematical model of UAV power supply system is developed, consisting of a set of solar cells, a set of electric batteries and a subsystem of transmission and distribution of electricity. The mathematical apparatus was based on the indicators of solar radiation power, the level of battery charge, the efficiency of electric batteries and solar cells, and geographical coordinates as well as the height of the aircraft position. In this case, the basic model was improved through the inclusion of algorithms for the analysis of losses of electric batteries and averaging the function of solar radiation power by time in accordance with the set of time ranges. The mathematical apparatus for calculation and optimization of aerodynamic parameters of UAV was also suggested on the basis of such indicators as the coefficient of lifting force, drag coefficient, air density as a function of flight altitude and total wing area of the aircraft. The suggested methods of analysis of structural features of HALE-class UAV provide an opportunity to both build automated evaluation algorithms and to carry out the procedure of expert evaluation of aircraft through the analysis of the corresponding dependencies: the ratio of the lifting force factor on the angle of attack and the drag coefficient, the ratio of the lifting force and aerodynamic resistance as a function of the drag coefficient, the dependence of the specific power on the load on the wing produced by the height of the UAV aircraft.

GJRE-D Classification: *DDC Code: 697.78 LCC Code: TJ809.95, DDC Code: 510 LCC Code: TL574.W3*

PECULIARITIESOFUAVCONSTRUCTIONFORFLIGHTSATHIGHALTITUDES

Strictly as per the compliance and regulations of:

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V. Kharchenko α, O. Onyshchenko σ & H. Bahmanfar ρ

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I. Introduction

The active introduction of unmanned aerial vehicles (UAVs), observed during the last decade [1, 2], significantly expanded the instrumental basis of optical [3], chemical [4] and radio monitoring systems [5], and also provided fundamentally new opportunities for the organization of cargo transportation [6] and telecommunication systems [7] (Fig.1). At the same time, as noted by the researchers [8-10], the development of unmanned aviation systems of long-range action for flights at high altitudes will assist in covering with the help of UAV the important domains of satellite communications and satellite imagery, which today are characterized by extremely high estimate associated with the need to bring artificial satellites into the Earth's orbit.

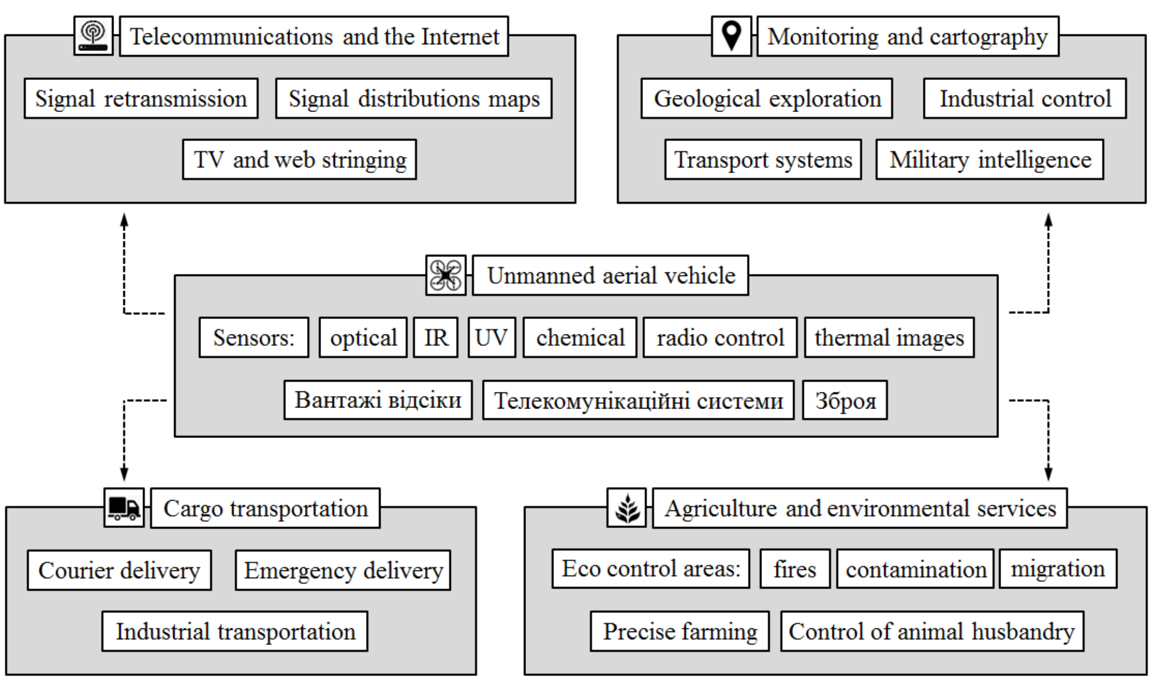

Figure 1: Areas of application of modern unmanned aviation systems

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This type of devices capable of non-stop staying at the level of tropopause and stratosphere for a long period of time, belongs to the class "HALE" (High-Altitude Long Endurance). To construct such devices, it is necessary to develop a power system of the device capable of functioning without providing fuel and maintenance, as well as to take into account the features of UAV flight at altitudes from 12-16 km above sea level (depending on the latitude, the indicator of which determines the level of tropopause). It should be noted that nowadays numerous projects on construction of HALE-class UAVs, among which ERAST [11], HALE UAV [12], Helios [13], HeliPLA [14] and Zephyr [15] are worth mentioning, did not show the desired results, which indicates the **relevance of this study**.

Analysis of scientific publications on this subject included papers that provide fairly simple and adequate models of calculation of average values of intensity of solar radiation and angle of incidence of sunlight [16, 17] as target functions from arguments of longitude, latitude and height of UAV dislocation, as well as time (time of year and time of day). Further, methods of optimization of the power supply system, which includes a system of solar cells and a set of electric batteries, which can be effectively applied in the construction of HALE-class UAV [17, 18], were determined. Finally, the results of practical research on the determination of dependence of change of UAV aerodynamic parameters on its height above the sea level [17-20] were considered. The analysis indicated the **unsolved part of the general task** in the field of construction of HALE-class UAV construction and was taken as the basis for further research. The **purpose of this paper**, thus was to develop a methodological base for improving the design of long-range UAV for flights at high altitudes, on the basis of which it would possible to construct algorithms for calculating the optimal parameters of these devices and provide appropriate guidelines for developers.

II. Methodology of the Study

As mentioned above, the basic classification of key elements, the peculiarities of which should be analysed in the construction of a mathematical model of HALE-class UAV, includes a power supply system. Power supply of this type of UAV is usually based on a system of solar cells located on the surface of the apparatus, which, due to the photoelectric effect, convert light energy into electrical energy. Another element of the power supply system is a set of electric batteries that are charged from solar panels at sufficient intensity of solar radiation and, in turn, ensure the operation of the UAV at a time when the intensity of solar radiation is insufficient (in general, the time interval can be divided into day and night time). The mathematical model, respectively, will include both the parameters of these subsystems, and the algorithm of optimal distribution of electricity, as well as the peculiarities of UAV functioning and factors related to the external environment that affect the level of electricity consumption (Fig. 2).

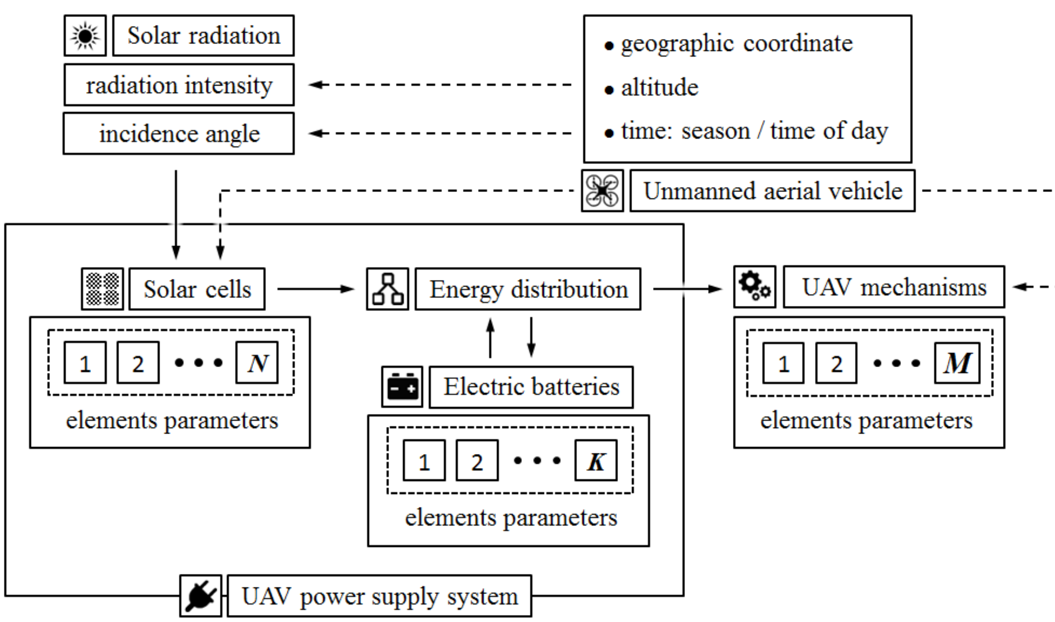

Figure 2: Basic scheme of organization of power supply system of HALE-class UAV

Thus, the mathematical model of the HALE-class UAV power system consists of the following elements:

- The power of solar radiation as a function of time $P_S(t)$, which can be averaged for certain periods of time $\int_{t_1}^{t_2} P_S(t)\,dt/(t_2-t_1)$ and determined in accordance with climatic conditions and seasons;

- The level of the battery charge P_{CH};
- Performance indicators of electric batteries η_{SB} (storage battery, SB) and solar panels η_{SC} (storage cell, SC), as well the coefficient of transmission losses in the system k_{TR} (transmittance factor, TR);
- Geographic coordinates of UAV: longitude λ and latitude φ, as well as the hourly angle, as a function of time $\omega_S(t)$, determining the position of the Sun.

On the basis of these values and functions, it is possible to determine the optimal values for τ the moment of switching to the battery charging mode and the moment of τ' switching to the battery usage mode according to the value of solar radiation power $P_0 = P_S(\tau) = P_s(\tau')$ and, respectively, to organize the distribution of the electric power within the system of UAV power supply.

Another important task is to simulate UAV flight and determine its aerodynamic parameters depending on the height of the device dislocation above the sea level. Obviously, when solving the optimization problem, the key arguments of the target functions will be the lifting force Y and aerodynamic resistance X, which, in turn, are determined on the basis of the following values:

- Coefficient of lifting force C_Y;
- Drag coefficient C_X;
- Air density as a function of UAV flight altitude — $\rho(h_{UAV})$;
- Total wing area of UAV — S_W;
- The relative speed of the UAV — v_{UAV}.

In this case, the value of the lifting force coefficient and the drag coefficient depends on the aerodynamic profile of the UAV, the angle of attack and the Reynolds number — Re.

On the basis of the suggested approach, it is possible to calculate and compare with experimental data the dependences for aerodynamic quality of UAV as the ratio of lifting force to aerodynamic resistance, specific power consumed by UAV in accordance with the flight mode, bearing capacity of UAV according to the load on the wing, etc.

III. Results of the Study

The analysis, which was carried out in the previous section, indicated that in order to calculate the optimal moment of switching between the mode of charging batteries and the mode of using batteries, it is necessary to average the function of solar radiation power by time. If at the level of the basic model we put the value $\eta_{SB} = 1$ (that is, we completely neglect the losses in the battery system), then the values τ and τ' can be determined through the solution of the following equation with respect to the variable t:

$$\tau = \tau' = t \text{ для } P_S(t) = \frac{\int_{t_{00}}^{t_{24}} P_S(t)dt}{\Delta t} \text{ при } \eta_{SB} = 0, \quad (1)$$

where $\Delta t = t_{24} - t_{00}$ corresponds to a time interval covering one full day. Fig. 3 shows such a solution as the determination of the coordinates of $P_S(t)$ and $\overline{P_S}(t)$ functions intersection.

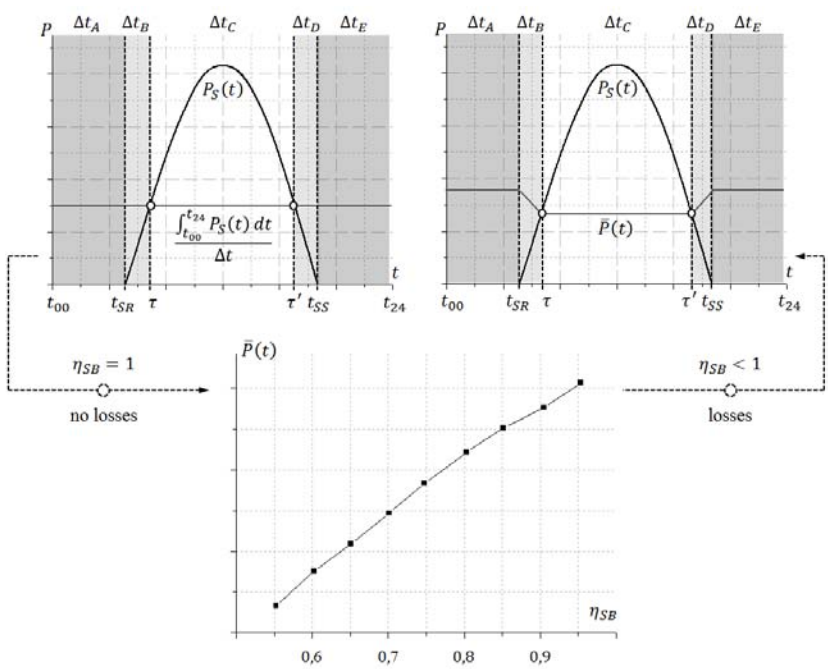

Figure 3: Algorithm for calculating the switching moment between the mode of charging batteries and the mode of using batteries

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However, the construction of an adequate mathematical model necessitates the analysis of losses of electric batteries, and therefore the consideration of $\bar{P}(t)$ as a complex function, the value of which depends on η_{SB} (as shown in Figure 3, the dependence is close to linear). In the framework of this study we would also like to consider the simplest situation, when the function of solar radiation power depends entirely on the position of the Sun (the case of cloudless weather or flight at extremely high altitudes). Accordingly, time range Δt can be divided into 4 time diapasons (Fig. 3, generalized dependencies $P_S(t)$ and $P_S(\eta_{SB})$ are averaging statistical data of works [16, 17]):

- Period of time before sunrise $\Delta t_A \in [t_{00}; t_{SR}]$, when the batteries operate in the power mode of the UAV system;
- The time interval from sunrise to switching batteries to the charging mode from solar cells $\Delta t_B \in [t_{SR}; \tau]$;
- The time interval from switching batteries to the charging mode from solar cells to switching to the power mode of the UAV system $\Delta t_C \in [\tau; \tau']$;
- The period of time from switching batteries to the power mode of the UAV system to sunset $\Delta t_D \in [\tau'; t_{24}]$;
- Period of time after sunset until the end of the day $\Delta t_E \in [\tau'; t_{24}]$.

Correlation of the coordinates of the UAV and the hour angle of the Sun provides an opportunity to determine the angle of incidence of sunlight on the surface of the solar cell:

$$\alpha = \frac{\pi}{2} - \cos^{-1}\big(\cos(\varphi)\cdot\cos(\lambda)\cdot\cos\big(\omega_S(t)\big) + \sin(\varphi)\cdot\sin(\lambda)\big), \quad (2)$$

on the basis of which the optimal value is calculated P_0:

$$P_0 = G_{SC}\cdot k_{TR}\cdot\eta_{SC}\cdot\sin\big(\alpha(\tau)\big), \quad (3)$$

where G_{SC} is the solar constant, SC, as the value of the total flux of solar radiation, per unit time and per unit area, oriented perpendicular to the flow. Accordingly, the UAV battery capacity is calculated on the basis of P_0 taking into account the time intervals:

$$\begin{cases} P_{CH} = P_{CH1} + P_{CH2} \\ \begin{bmatrix} P_{CH1} = \dfrac{P_0\cdot\Delta t_A}{\eta_{SB}} + \displaystyle\int_{t_{SR}}^{\tau}\left(\dfrac{P_0 - G_{SC}\cdot k_{TR}\cdot\eta_{SC}\cdot\sin\big(\alpha(t)\big)}{\eta_{SB}}\right)dt \\ P_{CH2} = \dfrac{P_0\cdot\Delta t_E}{\eta_{SB}} + \displaystyle\int_{\tau'}^{t_{SS}}\left(\dfrac{P_0 - G_{SC}\cdot k_{TR}\cdot\eta_{SC}\cdot\sin\big(\alpha(t)\big)}{\eta_{SB}}\right)dt \end{bmatrix} \end{cases}, \quad (4)$$

Considering that within the framework of the model the equality of $\Delta t_A = \Delta t_E$and $\Delta t_B = \Delta t_D$ gaps is accepted and the system of equations (4) can be simplified:

$$P_{CH} = 2\frac{P_0\cdot\Delta t_A}{\eta_{SB}} + \int_{t_{SR}}^{\tau}\left(2\frac{P_0 - G_{SC}\cdot k_{TR}\cdot\eta_{SC}\cdot\sin\big(\alpha(t)\big)}{\eta_{SB}}\right)dt. \quad (5)$$

Similarly, it is enough to calculate$\bar{P}(t)$ for three time ranges:

$$\begin{cases} \bar{P}(t) = \dfrac{P_0}{\eta_{SB}} \text{ для } t\epsilon[t_{00}; t_{SR}] \cup [t_{SS}; t_{24}] \\ \bar{P}(t) = \dfrac{P_0 - P_S(t)}{\eta_{SB}} \text{ для } t\epsilon[t_{SR}; \tau] \cup [\tau'; t_{SS}] \\ \bar{P}(t) = P_0 \text{ для } t\epsilon[\tau; \tau'] \end{cases}. \quad (6)$$

The suggested mathematical apparatus helps to determine areas (according to climatic zones), where HALE-class UAV can function autonomously for a sufficiently large period of time. When conducting cartographic research, it is sufficient to apply isomorphic lines calibrated according to the minimum permissible level $\bar{P}_S(t)$.

The next stage is calculation and optimization of aerodynamic parameters of UAV. As it was indicated in the previous section, the basis of mathematical modelling at this stage is the parameters of lifting force and aerodynamic resistance:

$$\begin{cases} Y = C_Y \cdot \dfrac{\rho(h_{UAV}) \cdot (v_{UAV})^2}{2} \cdot S_W \\ X = C_X \cdot \dfrac{\rho(h_{UAV}) \cdot (v_{UAV})^2}{2} \cdot S_W \end{cases} \rightarrow Y = \frac{C_Y \cdot X}{C_X}. \quad (7)$$

When calculating the lifting force of UAV aerodynamic profile of the wing is suggested to be modelled at the level of a two-dimensional problem. At the same time, the calculation of C_X is more non-trivial, for this purpose it is necessary to determine the drag coefficient C_{AD} (airfoil drag, AD), which can also be calculated for a two-dimensional model of the aerodynamic profile, the coefficient responsible for the component of the parasitic resistance C_{PD} (parasitic drag, PD) and is determined experimentally, as well as inductive resistance C_{ID} (induced drag, ID). In this case, the inductive resistance is calculated on the basis of the coefficient of lifting force and the indicator of the relative elongation of the wing k_{AR} (aspect ratio, AR). Based on these indicators, the drag coefficient is calculated as the sum:

$$C_X = C_{AD} + C_{PD} + \frac{(C_Y)^2}{k_e \cdot k_{AR}}. \quad (8)$$

where the coefficient k_e is based on the Oswald coefficient of efficiency for HALE-class UAV $k_e \approx \pi$. Adequacy of the suggested mathematical apparatus and its improvement in accordance with the specific task of UAV construction should be further checked on the basis of experimental tests, such as through the use of an aerodynamic tunnel.

Further work on modelling and optimization of UAV predetermines the introduction of the concept of thrust of the aircraft T, and determining its speed on the basis of the total mass value m_{UAV}:

$$v_{UAV} = 2\sqrt{(m_{UAV} \cdot g(h_{UAV}))/(\rho(h_{UAV}) \cdot S_W \cdot C_Y)}. \quad (9)$$

The value of the UAV speed can be taken as the basis for calculating the power used in the horizontal mode of flight of the device (level flight, LF):

$$P_{LF} = T \cdot v_{UAV} \rightarrow P_{LF} = \frac{Y \cdot C_X \cdot v_{UAV}}{C_Y} \rightarrow P_{LF} = C_X \cdot \sqrt{\frac{2}{S_W \cdot \rho(h_{UAV})} \cdot \left(\frac{m_{UAV} \cdot g(h_{UAV})}{C_Y}\right)^3} \quad (10)$$

Accordingly, the power density (power density, PD) for horizontal flight can be calculated as a ratio P_{LF} and S_{UAV}:

$$P_{LF}^{PD} = C_X \cdot \sqrt{\frac{2}{\rho(h_{UAV})} \cdot \left(\frac{m_{UAV} \cdot g(h_{UAV})}{S_W \cdot C_Y}\right)^3}. \quad (11)$$

It should be noted that dependence $P_{LF}^{PD} \sim (\rho(h_{UAV}))^{-\frac{1}{2}}$ allows to construct dependence of load on a wing P_{LF}^{PD} in accordance with specific design peculiarities of UAV for different heights of horizontal flight. The indicator characterizing the HALE-class UAV in accordance with the possibilities of its optimization is the coefficient of bearing capacity C_M, calculated as the ratio of mass of the bulk of the UAV (constant mass) — M_C and the mass of the elements to be optimized during the revision of the device, i. e. wings and solar panels that cover them - M_W (total mass $M_\Sigma = M_C + M_W$). Thus it is expedient to define M_W as product of index of density ρ_W and total area of wing of UAV:

$$C_M = \frac{M_\Sigma - \rho_W \cdot S_W}{M_\Sigma}. \quad (12)$$

As shown by the results of practical studies, for successful series of UAVs, the indicator C_M represents a fixed value [21-24] lying within the limits $C_M \in [0{,}15; 0{,}22]$.

It should be noted that this approach is basic, and in solving the practical problem of developing a HALE-class UAV, the classification of components of the apparatus according to the extent to which these components are subject to optimization should be more detailed.

IV. Analysis of the Results

The conducted research on definition of principles of construction of long-range UAV for flights at high altitudes provided an opportunity to develop a methodological base that can be applied during the analysis of structural peculiarities of aircraft of the specified class in order to optimize them in accordance with the goals set. The work included modelling of the power supply system and aerodynamic parameters of the UAV. In this section, on the basis of the constructed models, we are going to suggest to develop a scheme of complex analysis, which can be used by developers in the construction and optimization of corresponding aircraft.

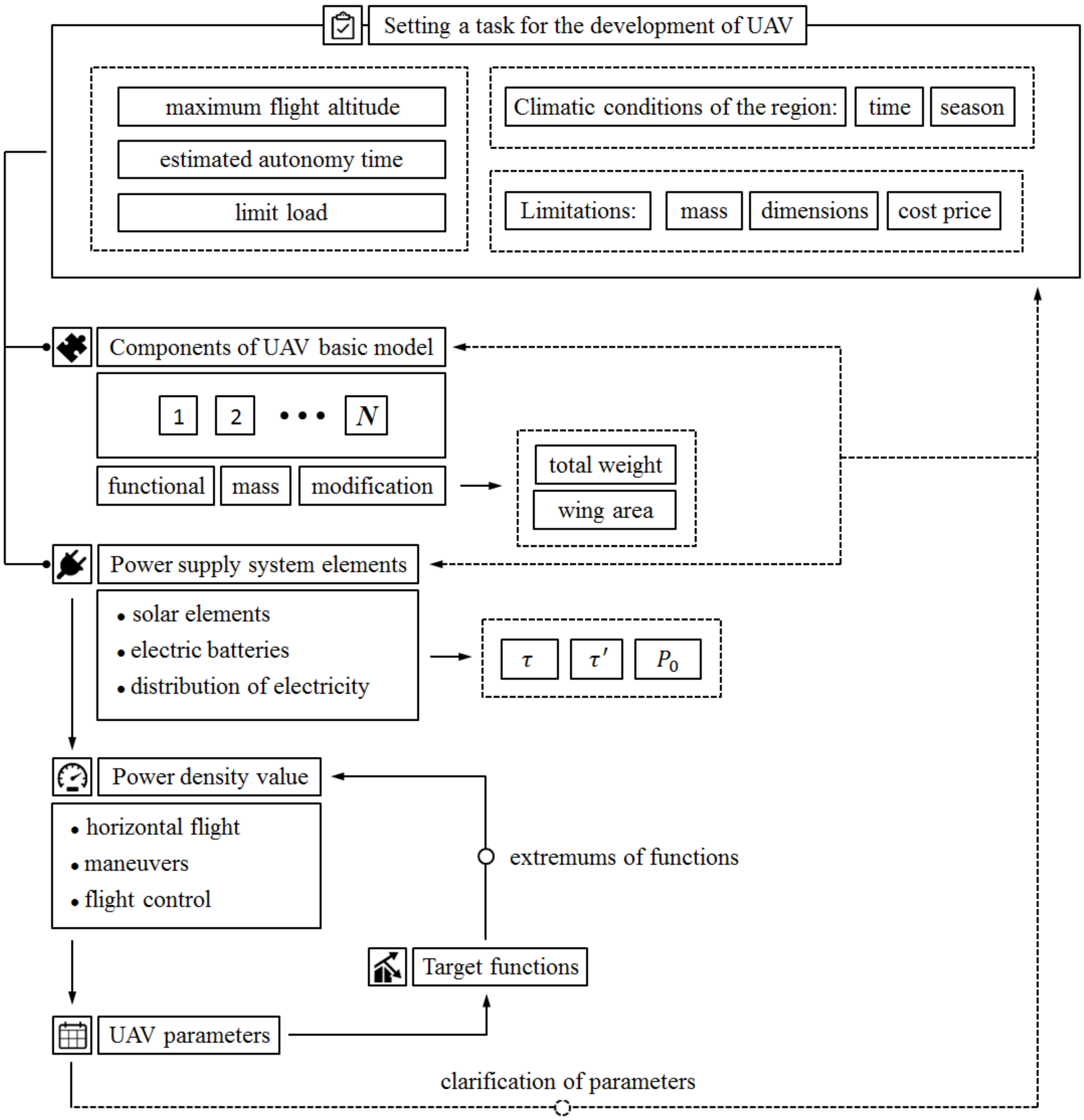

Figure 4: Complex methodology of optimization of functional components of HALE-class UAV

This scheme includes the following stages (Fig. 4):

- Determination of the conditions of the problem put before the developers of UAV: the desired values of the altitude of flight and the time of autonomous functioning of the device, as well as the amount of additional load that is planned to be used in the process of work, climatic conditions of the region, respectively, the average and minimum values of the solar irradiation per day depending on the season, limitation of the mass and dimensions of the device, the overall estimate of the project, etc.;
- Classification of components of the base model of UAV in accordance with the functional purpose, weight and possibility of further modification or replacement in the process of model improvement;
- Determination of total weight and total area of UAV wings;
- Classification of elements of the power supply system, which includes such groups as solar cells, electric batteries and subsystem of transmission and distribution of electricity;
- Determination of parameters of components of a power supply system and construction of basic algorithm of switching between modes of charging the batteries and usage of the batteries;
- Derivation of equations for calculating the level of specific power of consumption of electricity used in

the horizontal mode of flight of the device (depending on the task, losses on manoeuvres, payload, power supply of the flight control system can be calculated, etc.);

- Iterative process of finding optimal parameters of UAV, which is carried out at the level of establishing the extremes of target functions, determined according to the conditions of the task of UAV construction of UAV;
- Specification of initial conditions and basic model if necessary.

It should also be noted that at the level of expert evaluation it is important to analyse the dependencies that can be obtained during the implementation of the above stages: the dependence of the lifting force factor on the angle of attack and the drag coefficient, the ratio of the lifting force and aerodynamic resistance as function on the drag coefficient, the dependence of the specific power on the load on the wing produced by the height of the UAV, etc.

V. Conclusions

The conducted analysis showed that the development of unmanned aviation systems of long-range action for flights at high altitudes provides an opportunity to significantly expand the field of application of UAVs and, in particular, dramatically reduce the estimate of satellite communications and satellite imagery. At the level of elaborating the methodology of research of HALE-class UAV, key parameters that affect the efficiency of this type of devices in accordance with a wide class of tasks were determined. A mathematical model of UAV power supply system during autonomous operation was developed, consisting of a set of solar cells, a set of electric batteries and a subsystem of transmission and distribution of electricity. The suggested mathematical apparatus is based on the following indicators: solar power function on time, the level of charge of the electric battery, performance indicators of electric batteries and performance indicators of solar cells, geographical coordinates (longitude and latitude), as well as the height of the position of the aircraft. According to the instrumentation, which included the suggested mathematical apparatus of the model of the UAV power system model, the analytical solution of the problem of optimizing the consumption and accumulation of electricity by the aircraft was obtained. The next stage of the study was to work on improving the basic model by including algorithms for the analysis of losses of electric batteries and averaging solar power function by time according to the set of time ranges that reflect the level of solar radiation power. In addition, a mathematical model of the aircraft for calculating and optimizing the UAV aerodynamic parameters was developed. This model is based on such indicators as the coefficient of lifting force, drag coefficient, air density as a function of the flight altitude and the total wing area of the aircraft. Analysis of results of modelling of UAV aerodynamic parameters of indicated the need to introduce the function of thrust of the aircraft and the coefficient of bearing capacity. As a result of the conducted research, a comprehensive method for automating the process of improving the UAV design in accordance with the task was created and methodological recommendations for UAV developers were given. The suggested approaches and developed tools for the analysis of structural features of HALE-class UAV provide an opportunity to build automated algorithms for estimating the parameters of the aircraft and to organize the procedure of expert evaluation of the design through analysis of such dependencies as the ratio of the lifting force factor on the angle of attack and the drag coefficient, the ratio of the lifting force and aerodynamic resistance as a function of the drag coefficient, the dependence of the specific power on the load on the wing produced by the height of the UAV aircraft. It should separately mentioned, that the correspondence of the suggested mathematical apparatus and the possibility of its further improvement in accordance with the specific task should be checked on the basis of experimental tests.

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Global Journals follows the definition of authorship set up by the Open Association of Research Society, USA. According to its guidelines, authorship criteria must be based on:

1. Substantial contributions to the conception and acquisition of data, analysis, and interpretation of findings.
2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

Changes in Authorship

The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

Copyright

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Appealing Decisions

Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

Declaration of funding sources

Global Journals is in partnership with various universities, laboratories, and other institutions worldwide in the research domain. Authors are requested to disclose their source of funding during every stage of their research, such as making analysis, performing laboratory operations, computing data, and using institutional resources, from writing an article to its submission. This will also help authors to get reimbursements by requesting an open access publication letter from Global Journals and submitting to the respective funding source.

Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.
22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.
23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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