## Editorial Board

**Global Journal of Research in Engineering**

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On Standards of Seakeeping

By Victor A. Dubrovsky

Abstract- One from the main characteristic of a sea-going ship is seaworthiness. It defines the safety of sailing, comfort of using and service at sea. The complete characteristic includes some partial ones, and some of them contradict to others. A lot of standards of seakeeping were proposed by various authors from the middle of the XX century, some propositions are shown by the table. It means the practical need for official standards of seakeeping. The proposed standards belong to higher habitability, restriction of external loads, ensuring a ship service.

The introduction of seakeeping standards to classification rules is proposed. For example, the shown dependencies of sailor workability can be used for restriction of the motion and acceleration amplitudes. The standards, which ensure strength of structures and equipments, can be various for ships of various purposes.

Formal standards of seakeeping can be used for based comparison of various ships of the same purpose by the previously proposed method of seakeeping estimation by one digit. It allows the simple definition of price of a time unit (a hour or a month, for example) of the ship service at sea.

Keywords: seakeeping, standards, classification, motions, slamming, wet deck.

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Strictly as per the compliance and regulations of:
On Standards of Seakeeping

Victor A. Dubrovsky

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Keywords: seakeeping, standards, classification, motions, slamming, wet deck.

I. Introduction

One from the main characteristic of a sea-going ship is seaworthiness. It defines the safety of sailing, comfort of using and service at sea. The complete characteristic includes some partial ones, and some of them contradict to others. A lot of standards of seakeeping were proposed by various authors from the middle of the XX century, some propositions are shown by the table. The proposed standards belong to higher habitability, restriction of external loads, ensuring a ship service. The table contains some proposed standards.

Table 1: Some Proposed Standards of Seakeeping. [1]

<table>
<thead>
<tr>
<th>№</th>
<th>Year, author, ship.</th>
<th>Wetness</th>
<th>Slamming</th>
<th>Acceleration</th>
<th>Pitch</th>
<th>Roll</th>
<th>Bare propeller</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1972, Lipis, Kondrikov, «storm diagrams»</td>
<td>3 cases at 100 sec, Frame 20</td>
<td>1 case at 500 sec.</td>
<td>0.4g at Frame 20.</td>
<td></td>
<td></td>
<td>1 danger. case at 5 hours</td>
</tr>
<tr>
<td>2</td>
<td>1974, Aertssen, Container carrier</td>
<td>7 cases at 100 sec, Frame 20</td>
<td>3 cases at 100 sec, Fr. 17</td>
<td>0.4g Fr. 20.</td>
<td></td>
<td></td>
<td>25 cases at 100 sec</td>
</tr>
<tr>
<td>3</td>
<td>1974, Ochi,</td>
<td></td>
<td></td>
<td>Possibility 0.4g at Fr. 20 – no more 7% for full load, no more. 3% - for ballast</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1975, Connoly, Frigate, destroyer</td>
<td>1 case at 110 sec, Fr.20</td>
<td>1 case at 1360 sec, Fr. 16</td>
<td>Less 1 at 673 sec, Fr. 16.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1975, Tasaki, Takerava, Takaishi, cargo</td>
<td>Possib. Less 0.01</td>
<td>Possib. less 0.01</td>
<td>Possib. more 0.8g - 0.001 Ft. 20, Possib. more 0.6g – 0.01 at bridge</td>
<td>Possib. more 25 deg.- 0.001</td>
<td>Blade tip possib. – 0.1, 0.3 diam. – 0.1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1976, Moiseeva, fish-tech. base, Fishery ship</td>
<td></td>
<td></td>
<td></td>
<td>Ampl.3% -7 degr., Ampl.3% - 18degr.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1979, Chilo, cargo</td>
<td>Possib. 7% at Fr. 20.</td>
<td>Possib.3% at 3 Fr.17</td>
<td>0.4g at Fr. 20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1980, Comstock, Aircraft carrier</td>
<td></td>
<td></td>
<td></td>
<td>0.4g all, 0.2g- bridge</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Author: e-mail: multi-hulls@yandex.ru
<table>
<thead>
<tr>
<th>Case Study</th>
<th>Year</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hull • Hull (Swath)</td>
<td>1982, Landsburg, Tanker</td>
<td>6 cases at 100 sec, Fr.17 0.5g at Fr.20 0.4g – at bridge 30 degrs. 25 cases at 100 sec.</td>
</tr>
<tr>
<td>Elevator</td>
<td></td>
<td>Level displ. No more 7.65 m</td>
</tr>
<tr>
<td>Flying Deck, SWATH</td>
<td></td>
<td>No more 25% of diameter</td>
</tr>
<tr>
<td>Usual aircraft</td>
<td></td>
<td>1 deg., vert. velocity 2 m/sec, stern 5 degrs.</td>
</tr>
<tr>
<td>Vert. Fly-Off</td>
<td></td>
<td>3 degrs. 5 degrs.</td>
</tr>
<tr>
<td>Forhelic.</td>
<td></td>
<td>less 0.2g</td>
</tr>
<tr>
<td>Radar</td>
<td></td>
<td>less 25 degrs</td>
</tr>
<tr>
<td>Crew, Full Workab.</td>
<td></td>
<td>less 0.1g 3 degrs. 8 degrs.</td>
</tr>
<tr>
<td>The Same, 50% Workability.</td>
<td></td>
<td>Vertical. 0.35g, horiz. 0.15g</td>
</tr>
<tr>
<td>The Same, 10% Workability.</td>
<td></td>
<td>Vert. 0.5g, horiz. 0.2g 7.5 degrs. 20 degrs.</td>
</tr>
<tr>
<td>Level A</td>
<td>1984, Gerritsme:</td>
<td>30 at hour 20 at hour Vert. 0.4g, horiz. 0.2g, vert. speed 0.2m/sec 3 degr. 5 degr.</td>
</tr>
<tr>
<td>Level B</td>
<td></td>
<td>30 at hour 20 at hour 0.4g &amp; 0.2g 3 degr. 10 degr.</td>
</tr>
<tr>
<td>Level C</td>
<td></td>
<td>50 at hour 50 at hour 0.4g &amp; 0.4g 8 degr. 30 degr.</td>
</tr>
<tr>
<td>Free board at Fr.20</td>
<td>1984, Petrie, Bongort</td>
<td>9.76 m, vert. speed 4.2 m/sec Less, than 0.4g for upper raw of cont. 40 degr. For cargo Axe deep 5.5m</td>
</tr>
<tr>
<td>30 at hour at Fr.20</td>
<td>1985, Creight, Stahl: destroyer</td>
<td>20 at hour at Fr.17. 0.4g at Fr. 14 3 degr. 5 degr.</td>
</tr>
<tr>
<td>Frigate</td>
<td></td>
<td>same same At Fr. 15 same same</td>
</tr>
<tr>
<td>Swaship</td>
<td></td>
<td>30 at hour, Fr. 18 same At Fr. 18 same same</td>
</tr>
<tr>
<td>20 at hour, Fr.20</td>
<td>1986, Kent, Battle ships</td>
<td>20 at hour</td>
</tr>
<tr>
<td>1987, Karppinen, crew:</td>
<td></td>
<td>Short Time 0.275g Light Profess. Work 0.2g Hardwork 0.15g Long Time Sailing 0.1g</td>
</tr>
</tbody>
</table>
Let us note, the shown standards are proposed for displacement ships or for ships of the transient speed mode. And it must be noted, the horizontal accelerations decrease the labor productivity more strongly, than vertical acceleration. Then the restrictions of the firsts is twice bigger, than the seconds. The table does not contain the standards of acceleration of planning boats, which are bigger, than shown, at about an order – and decreasing of the accelerations of planning boats can`t be decreased by any measurements.

It can be supposed, the shown values of standards correspond to 14-% repeatability, i.e. are so named “sufficient” values.

### Table: Standards of Seakeeping

<table>
<thead>
<tr>
<th>Year</th>
<th>Code</th>
<th>Description</th>
<th>Acceleration</th>
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</thead>
<tbody>
<tr>
<td>16</td>
<td>1</td>
<td>1988, Kehoe 1 at minute</td>
<td>1 at min. Fr. 17</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
<td>1988, Luis 10 at hour Fr. 20</td>
<td>5 at hour</td>
</tr>
<tr>
<td>18</td>
<td>3</td>
<td>1988, Lloid 1 at 100 sec. Fr. 20</td>
<td>Shock accel. At island – less 0.05g</td>
</tr>
<tr>
<td>19</td>
<td>4</td>
<td>1988, OTAN standards:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>USA</td>
<td>0.2g at bridge 5 deg. 8 deg.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The Netherlands</td>
<td>0.16g at Fr. 16 The same The same</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Germany</td>
<td>0.18g at Fr. 20 The same The same</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UK</td>
<td>0.14g at mass center The same The same</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Canada</td>
<td>0.2g at Fr. 16 The same The same</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>1988, USSR, Fishery Ministry</td>
<td>Middle free boardmore 0.13 of overall beam; Bow free boardmore 0.3 of overall beam.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( K_i = (\sigma^2 + \sigma^2 + \sigma^2)^{0.5} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( Yz \ K_2 = (\sigma^2 + x \sigma^2, y) )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( K_3 = (\sigma_{\text{roll}}^2 + \sigma_{\text{pitch}}^2)^{0.5} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The same</td>
<td>standard of i-th process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( K_1 = 0.08g )</td>
<td>K3 = 4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At Bridge</td>
<td>( K_1 = 0.15g, K_2 = 0.2g )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At Engine Room</td>
<td>( K_1 = 0.15g, K_2 = 0.2g )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At Upper Deck</td>
<td>( K_2 = 0.12g )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At Cook</td>
<td>( K_2 = 0.15g )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At Passenger Apartments</td>
<td>( K_2 = 0.16g )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At Process Apartment</td>
<td>( K_2 = 0.18 )</td>
</tr>
<tr>
<td>21</td>
<td>6</td>
<td>1992, Wilson 30 at hour 20 at hour</td>
<td>Vertical. 0.4g, Horiz. 0.2g for crew</td>
</tr>
</tbody>
</table>

1. Establishment of seakeeping standards by classification societies.

It can be supposed, establishment of seakeeping standards can promote the seakeeping increasing, i.e. higher habitability and bigger safety of sea-going ships.

Today the contemporary level of science development (accessibility of the experimental method of seakeeping prediction and fast development of digital methods of prediction) allows introduction of such standards for most wide-spread types of ships, as a minimum.

It seems the standards must be divided by the aims of using for their wider applicability.
The standards, which are connected with labor productivity and rest conditions, and with ensuring of permissible conditions of structures and equipment exploitation, must be general ones for all types of ships.

Evidently, these standards will be applicable only for not combat ships, and for displacement or transient modes of speed regimes. Possible, such general standards will be established for ships, which are classified by corresponded societies, and by ship owners for the other ships.

2. Standards, which define the conditions of labor productivity.

These standards can be established, for example, on the base of special researching of Japan scientists.[1].

Figure 1 contains the dependence of various labor productivity from vertical accelerations of motion.

The comparison the data of Fig. 2 with the proposed standards from the Table (3 and 5 degrees) shows the smaller restriction not changes the productivity of any labor. But the second restriction leads to labor productivity at about 30%.

Figure 3 contain the dependence of labor productivity from roll amplitudes.

3. Standards, which are connected with conditions of structures and equipment exploitation.

Such standards, firstly, include number (or frequency) of slamming of any structures. The characteristic ultimately defines the shock loads from slamming: bigger frequency of slamming usually means higher shock loads. Of course, straight measurement of shock loads gives most exact picture of such loads. But, unfortunately, the maximal load placement can`t be defined previously... Than limitation of shock number seems more simple and convenient method. For example, it can be no more, than 20 shocks per a hour, referring to practical experience.

If more danger of wet deck, than of slamming, will be taken into account, possible, number of wet deck cases must be no bigger, than 20 cases at a hour too.

It seems, the permissible frequency of propeller baring, must be connected with characteristics of the equipment, which restricts the frequency.

II. Conclusions, Recommendations

1. Permanently repeated propositions of seakeeping standards mean the practical need of official introduction them to classification rules of registers.
2. Introduction of seakeeping standards will stimulate wider examination of seakeeping characteristics by experiments and calculations and introduction of motion mitigation methods and ship types with higher seakeeping.

3. The method of seakeeping estimation by one digit [2] is recommended for wide using after introduction of corresponded standards. Some other restriction of seakeeping characteristics, which correspond to a ship purpose, can be used together with official standards.

**References Références Referencias**


Creep Fatigue of Solder Joints in Electronic Assemblies

By E. H. Wong

Abstract- Electronic assembly is formed by mechanically joining, and hence electrically interconnecting, integrated circuit components onto printed circuit board using arrays of solder joints. Differential thermal expansion between the integrated circuit component and the printed circuit board leads to failure of solder joints through the combined mechanisms of creep and fatigue. This manuscript condenses the recent advances in creep fatigue analysis of solder joints in electronic assemblies into two major analyses: thermomechanical analysis and creep fatigue life modelling. The analytical thermomechanical analysis models an electronic assembly as a sandwich structure. By modelling the actual geometry of solder joints, it has found stout hourglass to be the ideal shape for solder joints that could reduce the magnitude of stress by 80% compared to the standard barrel-shape solder joints. The new creep integrated fatigue equation integrates the fundamental equation of creep into fatigue life equation and has been shown to model very well the creep fatigue of solder alloy.

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I. Introduction

The motherboard assembly constitutes morphologically the brain of an engineering device. The integrated circuits that are photolithographically etched onto silicon chips constitutes morphologically the brain cells. However, the brain cells on individual silicon chip are isolated from other chips; and they need to be electrically interconnected. The brain cells are very delicate and even the interconnects are mechanically fragile; and they need to be mechanically protected. Lastly, the brain cells generate high intensity of heat when running, and the heat needs to be dissipated before the brain cells would be burned. The jobs of electrical interconnection, mechanical protection, and thermal dissipation rest on the design and engineering of electronic and microelectronic assemblies [1].

Figure 1 shows the schematic of a silicon chip that is electrically interconnected to a substrate, which is in turn interconnected to a printed circuit board, through arrays of solder joints. The former assembly is frequently referred to as an integrated circuit component/assembly while the latter is frequently referred to as a printed circuit board assembly. We shall refer to both assemblies as simply electronic assemblies. The solder joints are formed by melting solder balls/paste to form metallurgical bonds with the metal pads on the chip and the substrate, and with the metal pads on the substrate and the printed circuit board.

Electronic assemblies are susceptible to undue stress during manufacturing and while in service resulting in functional failure. In general, electronic assemblies may experience three main physics of damage: the violent vaporisation of the ingress moisture in the integrated circuit assembly during the solder joint forming process leading to cracking and/or delamination of the assembly [2][3]; fracturing of interconnection caused by drop-shock of mobile electronic products [2][4]; and lastly, creep-fatigue damage of interconnecting solder joints after repeated cycles of powering on/off of engineering devices [2][5]. The last is especially critical and has attracted maximum interest in...
Electronic assemblies. In essence, the differential thermal expansions between the silicon chip and the substrate and between the integrated circuit assembly and the printed circuit board give rise to cyclical deformation of the solder joints at temperature above their homologous temperature, driving them towards failure by the mechanism of creep fatigue. The propensity for creep fatigue failure of solder joints is aggravated by the trend towards increasing functionality of consumer electronic products, which is driving increase size of integrated circuit assembly and reduce size of solder joints.

The failure of a nuclear plant or a commercial aircraft is accompanied by unacceptable catastrophic consequences. The structural integrity and reliability of such products are therefore the paramount design considerations. In contrast, the two paramount design considerations for electronic assemblies are electrical performance and space. The former to support the ever-increasing performance of electronic products and the latter to support the increasing functionality of electronic products. Failure of consumer electronic products in service though annoyable is acceptable to most users. This has encouraged a relatively relax attitude towards the structural integrity of electronic assemblies; and this is further encouraged by the relatively short life cycle of consumer electronic products. Nevertheless, there is a positive aspect of this more relax attitude towards structural analysis. The structural design of electronic assemblies is not bounded by a design protocol or a design code. Electronic assembly engineers are free to use any analysis method so long as the designed electronic assemblies will meet the integrity and reliability test requirements. It is inherently easy to monitor the structural integrity of an electronic assembly through monitoring the electrical connectivity of the assembly [6]. If necessary, the growth of damage in an electronic assembly can be tracked in real time through monitoring the changing electrical impedance of the assembly [6][7]. The absence of a strict design protocol and the ease of validating an analysis with tests has encouraged the exploration and adoption of new analysis methods, notwithstanding some of these methods may not be robust.

This manuscript gives a condensed presentation of the recent advances in the creep fatigue analysis of solder joints in electronic assemblies. This comprises two major analyses: thermomechanical analysis of solder joints in electronic assemblies; and creep fatigue life modelling of solder joints. It is believed that these advanced analyse techniques are fundamentally robust and they can be adopted to similar applications in other engineering field.

II. Thermomechanical Analysis of Solder Joints

Electronic assembly engineers routinely performed thermomechanical analysis of electronic assemblies using finite element analysis software in which the solder joints are modelled using solid finite elements. This has inadvertently led to singularity of stress/strain at discontinuities of geometry and materials giving rise to inconsistent analysis - because the magnitude of the stress/strain is dependent on the size and shape of the finite element at the site of singularity. To circumvent such singularity, electronic assembly engineers have adopted the practice of volume-averaging the stress/strain over a selected volume of solder joints [8][9]. Unfortunately, such arbitrary volume averaging act is equivalent to smearing the geometry of solder joints, effectively denying the engineers the ability to analyse the geometrical effects of solder joints on the magnitude of stress/strain. The issue of stress/strain singularity can be addressed by modeling the components of electronic assemblies as shells and beams. Maximum insights into the mechanics of the subject matter can be achieved through analytical modeling.

Analytical models of varied sophistication have been reported in the electronic assembling community [10][11][12][13]. In essence, an electronic assembly is treated as a sandwich structure constituting of array of solder joints sandwiched between two outer members. The simplest model treats the outer members as being infinitely rigid.
and the solder joints as being infinitely compliant such that the solder joints experience only shear strain whose magnitude increases linearly with distance from the neutral plane of an electronic assembly and is given by \( \gamma = \Delta \alpha T \cdot x / h \) (Figure 2a) [10], where \( \Delta \alpha T \) is the differential thermal strain between the two outer members, \( x \) is the distance of a discrete joint from the neutral plane of the assembly, and \( h \) is the height of the discrete joint. This unrealistic model would grossly overestimate the magnitude of shear strain. The more sophisticated models treat the outer members as rectangular beams; and the solder joints as linear springs [11], or as cylindrical beams that are capable of shearing, flexing, and stretching [12][13]. The inclusion of elasticity of the outer members in the model have led to the vital understanding that shear strain in the solder joints does not increase linearly but exponentially with distance from the neutral plane of an electronic assembly. It takes the form \( \gamma = \gamma_0 e^{\beta (x-l)} \) (Figure 2b), where \( \gamma_0 \) is approximately the shear strain at the outmost solder joint, \( \beta \) is a compliance parameter of the assembly, \( l \) is the half-length of the assembly.

\[ \gamma = \Delta \alpha T \cdot x / h \]

\[ \gamma = \gamma_0 e^{\beta (x-l)} \]

**Figure 2:** Analytical Models with Closed-Form Solution: (a) Infinitely Rigid Outer Members; (b) Outer Members as and Solder Joints as Elastic Beams

a) **Analytical Modelling**

Evaluating the stresses in the discrete joints of an assembly involves four steps of analysis, starting with smearing the discrete joints into a continuously bonded joint and then evaluating the compliances of the smeared assembly. This is followed by evaluating the smeared stresses in the smeared joints. The third step integrates the stresses into boundary forces and moments acting on individual discrete joint. The last step evaluates the stresses in the discrete joint due to the boundary forces and moments.

The discrete joints are assumed to be of identical shape and size and are distributed at uniform spacing. Figure 3 shows the schematic of discrete joints with a height \( h_d \) and spacing at pitches \( p_x \) and \( p_y \) along the \( x \) and the \( y \) coordinates, respectively. In the case that individual discrete joint is not of cylindrical shape but one with non-uniform sections along its height, it is represented by a pseudo cylindrical joints with a representative shear area, \( A_{d,rep} \), and a representative second moment of area, \( I_{d,rep} \), that would return identical shear and flexural stiffnesses as the original discrete joints [14]. Theses representative parameters are given by
Referring to the outer members as member #1 and member #2, and the discrete joint as member #\(d\), the height, the stretch modulus, the shear modulus, and the flexural stiffness of member #\(i\) are denoted as \(h_i\), \(E_i\), \(G_i\), and \(D_i\), respectively; the shear and the in-plane stretch compliances of the assembly are denoted as \(\kappa_s\) and \(\lambda_s\) respectively. For ease of reference, we shall refer to the moduli of the smeared joints as smeared moduli and the compliances as smeared compliances. Those characteristics that are associated with the smeared joints will be marked with an asterisk.

\(\text{b) Compliances of a Smeared Assembly}\)

The in-plane stretch compliance of the assembly is a function of the outer members and, for the case of plane stress, is given by \([12][13]\)

\[
\lambda_x = \sum_{i=1}^{2} \left( \frac{1}{E_i} \frac{h_i}{4D_i} \right),
\]

where \(D_i = E_i h_i^3 / 12\) for plane stress. The smeared shear compliance of the assembly, \(\kappa_s^*\), is given by \([12][13]\)

\[
\kappa_s^* = \sum_{i=1}^{2} \kappa_{si} + \kappa_{sd}^* + \kappa_{sd\phi},
\]

where

\[
\kappa_{si} = \frac{h_i}{8G_i}, \quad \kappa_{sd}^* = \frac{h_d}{G_d^*}, \quad \kappa_{sd\phi} = \frac{h_d^3}{12D_d^*}.
\]

wherein \(\kappa_{si}\) is associated with the shear compliance of member #\(i\); \(\kappa_{sd}^*\) is associated with the shear deformation of the smeared joints; while \(\kappa_{sd\phi}\) is associated with the flexural deformation of the discrete joints – referring to Figure 2b. The smeared shear modulus, \(G_d^*\), and the smeared flexural rigidity, \(D_d^*\), are given by \(G_d^* = G_d A_{d,rep} / (p_x p_y)\) and \(D_d^* = E_d I_{d,rep} / (p_x p_y)\).

\(\text{c) Stresses in Smeared Joints}\)

The shear stress in the smeared joints along the bonded length of a balanced assembly is given by \([12][13][15][16]\)

\[
\tau^*(x) = A_c^* e^{\beta^*(x-L)}, \quad x > 0,
\]

where

\[
A_c^* = \frac{E_p}{\sqrt{2\pi k_s}},
\]
\[ \beta^* = \sqrt{\frac{\lambda_x}{\kappa_S^2}}; \quad \epsilon_T = \Delta \alpha T \] is the differential thermal strain between the outer members.

d) **Sectional Force and Moment in a Discrete Joint**

The magnitude of the sectional shear force on a discrete joint that is at a distance \( \Gamma \) from the mid plane of the assembly may be evaluated approximately as

\[ F_{s}(\Gamma) \approx \tau^*(\Gamma) p_x p_y, \quad (7) \]

The sectional shear force does not vary along the height of the discrete joint. On the other hand, and referring to Figure 4, rotational equilibrium dictates that the sectional moment varies linearly along the height of the discrete joint and is given by

\[ m(\Gamma, z) = F_{s}(\Gamma) z, \quad (8) \]

where \( z \) is the local coordinate of a solder joint as shown in Figure 3.

e) **Shearing and Bending Stresses in a Discrete Joint**

The distribution of shear stress and bending stress along the height of a discrete joint, assuming it being an Euler beam, are simply [12][13]:

\[ \tau_d(\Gamma, z) = \frac{F_s(\Gamma)}{A_d(z)} \]

\[ \sigma_b(\Gamma, z) = m_s(\Gamma, z) \frac{r_d(z)}{I_d(z)} \quad (9) \]

where \( A_d(z) \), \( I_d(z) \), and \( r_d(z) \) are the local cross-sectional area, the local second moment of area, and the local outer fibre of the discrete joint. Assuming circular cross-section, as in the case of solder joints, the ratio \( r_d/I_d \) is reduced to \( 4/(\pi r_d^3) \).

The largest magnitudes of shear force and bending moment, and hence shearing and the bending stresses, occur at the discrete joint furthest from the mid-plane of the assembly. Assuming \( I_{max} = I \), these stresses are given by

\[ \tau_{d,max} = \frac{F_{s,max}}{A_{d,min}} \]

\[ \sigma_{b}(l, z) = \frac{4F_{s,max} \tau^*}{\pi r_d^4(z)} \quad (10) \]

where

\[ F_{s,max} = \frac{\epsilon_T p_x p_y}{\sqrt{\lambda_x \kappa_S}}, \quad (11) \]

and \( A_{d,min} \) is the minimum cross-sectional area of the discrete joint.
f) **Optimum Shape of Solder Joints**

The solder joints are formed through controlled heating of solder into liquid form followed by controlled cooling the assembly to room temperature, forming metallurgical bonds with metal pads at its two ends. A solder joint will take up the natural shape of a spherical barrel, as shown in Figure 5a, that has the minimum surface energy. It is clear from Eq. (10) that a standard solder joint will experience the maximum magnitude of shear stress, \(\tau_{d,max}\), and the maximum magnitude of bending stress, \(\sigma_{b,max}\), at its ends joining the outer members; and

\[
\frac{\sigma_{b,max}}{\tau_{d,max}} = \frac{2h_d}{r_{d,end}}
\]  

(12)

where \(r_{d,end}\) is the radius of the solder joint joining the outer member. In a standard barrel-shape solder joint, the magnitude of \(h_d\) is much larger than that of \(r_{d,end}\). In other words, \(\sigma_{b,max}\) is a far dominant stress in a standard barrel-shape solder joint. On paper, the magnitude of the dominant stress, \(\sigma_{b,max}\), can be lowered by increasing the end radius of barrel-shape solder joints, which for the same volume of solder joint, will result in flatten barrel-shape solder joints leading to very significant reduction in the magnitude of \(\sigma_{b,max}\). In practice, such a manipulation would inevitably raise the risk of bridging between adjacent solder joints, as is illustrated in Figure 5b.

It is clear from the linear distribution of bending moment in solder joints, as depicted in Figure 4, that solder joints should ideally have the shape of an hourglass. Solder joints of progressive hourglass shape can be designed into electronic assembly [14]. Modeling the curvature of an hourglass-shape solder joint as a hyperbolic sine curve and evaluating its representative shear area, \(A_{d,rep}\), and representative second moment of area, \(I_{d,rep}\), using Eq. (1), a stout hourglass-shape solder joint – similar to that illustrated in Figure 5c – has been found to return the minimum magnitude of stress for the same volume of solder as a standard barrel-shape solder joint. The maximum magnitude of bending stress, \(\sigma_{b,max}\), in the stout hourglass solder joints is less than 15% that in a standard barrel-shape solder joints [14]. It is also worth noting that the use of stout hourglass solder joints does not increase the risk of bridging between solder joints.

### III. Creep Fatigue Modeling

The fatigue life of a metal experiencing pure low cycle fatigue – that is, in the absence of aggravating element – and under a constant amplitude of cyclic stressing has been found to be satisfactorily modelled using the Coffin-Manson equation:

\[
\varepsilon_p = C_o N_f^{-\beta_o},
\]  

(13)
where $\epsilon_p$ is the amplitude of the incremental plastic strain in a cycle; $N_f$ is the number of cycles to failure; $C_o$ and $\beta_o$ are material dependent fitting constants. While it is tempting to extend the equation to creep fatigue modelling by replacing the plastic strain amplitude, $\epsilon_p$, with inelastic strain amplitude, $\epsilon_m = \epsilon_p + \epsilon_c$, wherein $\epsilon_c$ is the incremental creep strain in a single cycle, this simplicity approach of lumping creep strain with fatigue strain contradicts with the different macrostructural damages of creep and fatigue in metals [17][18] and has been convincingly disproved by abundant experimental data [19].

### a) A Brief Review of Practising Creep Fatigue Life Prediction Models

The power generation community and the aerospace engineering community have vast knowledge and experience in modelling creep fatigue life of metals. Both the power generation and the aerospace communities have subscribed to the idea that creep fatigue damage can be evaluated by summing independently the damages due to creep, due to fatigue, and due to interaction of these two damages. The summative creep fatigue damage in a single creep fatigue cycle may be expressed mathematically as

$$d = d_f + d_c + d_{cf}. \quad (14)$$

Interestingly, the two communities have subscribed to different idea of defining the respective damages, $d_f$, $d_c$, and $d_{cf}$.

The aerospace community characterises the three cyclic damage indices from the hysteresis loop of a tension-compression creep fatigue experiment. Three components of inelastic strain: $\epsilon_{pp}$, $\epsilon_{cc}$, $\epsilon_c$ (or $\epsilon_{cc}$) are partitioned and extracted from the hysteresis loop, wherein the first letter of the subscript (c for creep and p for plastic strain) refers to the type of strain imposed in the tensile portion of the cycle, and the second letter refers to the type of strain imposed during the compressive portion of the cycle. Individual strain component is assumed to follow a power-law relation with the number of hysteresis cycles to failure. That is,

$$\epsilon_{jk} = C_{jk}N_{jk}^{-\beta_{jk}}. \quad (15)$$

The damage per creep-fatigue cycle due to individual component is then simply

$$d_{jk} = \frac{1}{N_{jk}} = \left(\frac{\epsilon_{jk}}{C_{jk}}\right)^{1/\beta_{jk}}. \quad (16)$$

This is known as the strain range partitioning model [19]. While this noble model has served the aerospace community well, its characterisation is inherently challenging.

The power generation community conveniently treats the cyclic fatigue damage, $d_f$, as that due to pure fatigue, which can be evaluated using the Coffin-Manson equation; that is,

$$d_f = \frac{1}{N_f} = \left(\frac{\epsilon_p}{C_o}\right)^{1/\beta_o}; \quad (17)$$

and the cyclic creep damage, $d_c$, as that due to pure creep, which may be evaluated using the creep strain exhaustion rule:

$$d_c = \frac{1}{\epsilon_R} \int_0^t \dot{\epsilon}_c(t) dt, \quad (18)$$

wherein $\dot{\epsilon}_c(t)$ is the instantaneous creep strain rate and $t$, the cyclic period. However, the cyclic creep-fatigue interaction damage, $d_{cf}$, is a fitting index, which can only be established through extensive experimental characterisation [20][21][22].
The electronic packaging professionals have fallen for the creep fatigue equation of Darveaux [9],

\[ N_{cf} = K_1 w_{in}^{K_2} \]  

(19)

where \( w_{in} = w_p + w_c \) is the sum of the cumulative plastic work density and the cumulative creep work density in a single creep fatigue cycle. Just like the failed idea of substituting plastic strain with inelastic strain in Eq. (13), the act of lumping the two work densities is clearly against the macrostructural evidence of the two damages. Consequently, and unsurprisingly, the fitting constants, \( K_1 \) and \( K_2 \), are found to be dependent on the size and shape of individual electronic assembly [9], in other words, on the magnitude of the inelastic work density, \( w_{in} \). Nevertheless, the electronic packaging community have stubbornly stuck with the model.

b) Creep Integrated Fatigue Equation

In the case of fatigue being the dominant mechanism in creep fatigue failure, the role of creep may be treated as one to lower the material capacity in fatigue. This has led to the idea of creep integrated fatigue equation [23][24][25]:

\[ \varepsilon_p = C_0 c(\varepsilon_p, T, t_c) N_{cf}^{-B_0}, \]  

(20)

where \( c(\varepsilon_p, T, t_c) \) is a function. Expressing the fatigue capacity in Eq. (13) for the case of pure fatigue as \( \varepsilon_{p,ref} \) and it becomes clear that \( c(\varepsilon_p, T, t_c) = \varepsilon_p/\varepsilon_{p,ref} \) describes the fractional fatigue capacity of a subject in the presence of creep. Its magnitude ranges from zero to unity - a zero magnitude corresponds to the case of pure creep while a magnitude of unity corresponds to the case of pure fatigue. The function \( 1 - c(\varepsilon_p, T, t_c) \) describes the fractional creep damage acting on the subject.

i. The Fundamental Equations of Pure Creep In Metals

The strain rate in a uniaxial steady-stress creep rupture experiment may be described in the form of Sherby-Dorn equation, \( \dot{\varepsilon}_{SD} \), or Larson-Miller equation, \( \dot{\varepsilon}_{LM} \), or Manson-Haferd equation, \( \dot{\varepsilon}_{MH} \):

\[
\begin{align*}
\dot{\varepsilon}_{SD} &= f(\sigma_s)e^{-H/kT}, T \geq 0 \\
\dot{\varepsilon}_{LM} &= Be^{-H(\sigma_s)/kT}, T \geq 0 \\
\dot{\varepsilon}_{MH} &= De^{(T-T_{ref})r(\sigma_s)}, T \geq T_{ref}
\end{align*}
\]  

(21)

wherein \( f(\sigma_s), H(\sigma_s), \) and \( r(\sigma_s) \) are functions of the applied tensile stress, \( \sigma_s; k \) is the Boltzmann’s constant; \( H, B, \) and \( D \) are material dependent constants; and \( T_{ref} \) is the temperature below which the mechanism of creep is assumed to be dormant. Assuming the dominance of the secondary stage of creep, the eventual creep rupture strain, \( \varepsilon_R \), is given by

\[ \varepsilon_R = \dot{\varepsilon}_R t_r, \]  

(22)

where \( t_r \) is the time to creep rupture. Assuming \( \varepsilon_R \) to be independent of the applied stress and temperature, Eq. (21) may be rearranged into:

\[
\begin{align*}
P_{SD}(\sigma_s) &= \frac{\varepsilon_R}{f(\sigma_s)} = \frac{t_r}{e^{H/kT}} \\
P_{LM}(\sigma_s) &= \frac{H(\sigma_s)}{k} = \frac{\ln t_r + \ln B_R}{1/T} \\
P_{MH}(\sigma_s) &= \frac{1}{r(\sigma_s)} = \frac{T-T_{ref}}{\ln(t_r/t_{ref})}
\end{align*}
\]  

(23)
where $B_\infty = B/\varepsilon R$ and $t_\infty = \varepsilon R/D$. These functions are known respectively as the Sherby-Dorn parameter, the Larson-Miller parameter, and the Manson-Haferd parameter. These parameters describe the relations between the applied stress, $\sigma$, and the gradient of the respective time-temperature function. These relations can be readily characterized and are used extensively in the creep rupture design of metal structures.

The corresponding stress parameter for a single stressing cycle may be expressed as [25]:

$$P_{c,SD}(\sigma) = t_c e^{-H/kT}$$

$$P_{c,LM}(\sigma) = T(ln t_c + ln B_c),$$

$$P_{c,MH}(\sigma) = T - T_{ref} \frac{t_c}{ln(t_c/t_{coo})}$$

(24)

where $\sigma$ is the amplitude of the cyclic stress; and $B_c = B/\varepsilon c$, $t_\infty = \varepsilon /D$, and $\varepsilon_c$ is the cumulative creep strain in a single cycle. Assuming (i) identical creep damage due to tensile and compressive stresses, and (ii) linear cumulation of creep strain over varied magnitudes of stress, then the cumulative creep strain in a single cycle may be expressed as $\varepsilon_c = \int_0^{t_c} k(|\sigma(t)|, T) dt$, where the function $k(|\sigma(t)|, T)$ represents one of the rate equations of the SD, LM and MH; and $|\sigma(t)|$ is the instantaneous magnitude of the cyclic stress. The cyclic stress parameter function may then be evaluated mathematically from the steady-stress parameter function as [25]

$$P_{c,SD}(\sigma) = \frac{\phi_c t_c}{\int_0^{t_c} P_{SD}(|\sigma(t)|) dt}$$

$$P_{c,LM}(\sigma) = \frac{t_c}{\int_0^{t_c} P_{LM}(|\sigma(t)|) dt}$$

$$P_{c,MH}(\sigma) = \frac{t_c}{\int_0^{t_c} P_{MH}(|\sigma(t)|) dt}$$

(25)

where $\phi_c = \varepsilon_c/\varepsilon R$.

ii. Fractional Fatigue Capacity Function

Let the fractional fatigue capacity function $c(\varepsilon_p, T, t_c)$ takes the form:

$$c(\varepsilon_p, T, t_c) = 1 - \chi(\varepsilon_p) \eta(T, t_c).$$

(26)

Herein $\chi(\varepsilon_p) \eta(T, t_c)$ is the fractional creep damage function. It is intuitive that the function $\eta(T, t_c)$ shall take the form of the rate equation of creep; that is,

$$\eta_{SD}(T, t_c) = t_c e^{-H/kT}$$

$$\eta_{LM}(T, t_c) = T(ln t_c + ln B_c).$$

$$\eta_{MH}(T, t_c) = T - T_{ref} \frac{t_c}{ln(t_c/t_{coo})}$$

(27)

It is worth noting that $\eta(T, t_c)$ vanishes at $T \leq 0$ for $\eta_{SD}$ and $\eta_{LM}$ and at $T \leq T_{ref}$ for $\eta_{MH}$ when the mechanism of creep becomes dormant; the condition of pure fatigue prevails and the fractional fatigue capacity function $c(\varepsilon_p, T, t_c)$ acquires the maximum magnitude of unity. Similarly, the condition of pure creep requires that the magnitude of fractional fatigue capacity function vanishes to nil. This implies, from Eq. (24), that

$$X_k(\varepsilon_p) = \frac{1}{P_{c,k}(\sigma)},$$

(28)

wherein the subscript $k$ signifies $SD$, $LM$, and $MH$, respectively. The cyclic parameter function, $P_{c,k}(\sigma)$, can be evaluated from the steady-stress parameter function, $P_k(\sigma)$, using Eq. (25). Using the Ramberg–Osgood relation, $\sigma = \sigma_p = \varepsilon_0$,
\( R \varepsilon_p \bar{n} \), where \( R \) and \( \bar{n} \) are assumed to be the representative material constants over the range of temperature of interest, the cyclic parameters may then be expressed as a function of plastic strain; that is,

\[ P_{c,k}(\sigma) \rightarrow P_{c,k}(\varepsilon_p). \]  

(29)

The material dependent fitting constants, \( C_o, \beta_o, \bar{k}, \bar{n}, \) and \( \phi_o \) (the constant \( H \) may be evaluated from the steady-stress creep rupture test data) or \( B_c \) or \( t_{\infty} \), may be established through regressing the experimental creep fatigue data with Eq.(20). It is worth mentioning that the constants \( \bar{k}, \bar{n}, \) and \( \phi_o \) or \( B_c \) or \( t_{\infty} \) represent the damages due to pure creep and also creep-fatigue interaction.

In practice, one can do away with the experimental characterisation of the steady-stress parameter function, \( P_k(\sigma) \), and the subsequent mathematical evaluation of the cyclic parameter function, \( P_{c,k}(\sigma) \). By expressing the steady stress parameter function as a power law in the form \( P_k(\sigma) = p\sigma^q \), where \( p \) and \( q \) are fitting constants, it can be shown that the cyclic stress parameter function will be reduced to a power law function, \( P_{c,k}(\sigma) = \hat{p}\sigma^{\hat{q}} \), where \( \hat{p} \) and \( \hat{q} \) are constants, for the sinusoidal and the triangular stress-time profile. This could then be transformed to \( P_{c,k}(\varepsilon_p) \) using the Ramberg–Osgood relation. In other words, the function \( \chi(\varepsilon_p) \) may simply be assumed to be a power-law function,

\[ \chi(\varepsilon_p) = a\varepsilon_p^b, \]  

(30)

where \( a \) and \( b \) are arbitrary constants. These two arbitrary constants can be established together with three material dependent fitting constants \( C_o, \beta_o, \) and \( H \) or \( B_c \) or \( t_{\infty} \), through regressing the experimental creep fatigue data with Eq. (20). This shall be illustrated in the following section.

### iii. Illustration and Validation

The experimental creep fatigue data of Sn37Pb under cyclic triangular stress-time stressing generated by Shi et al. [26] has been analysed and the fitting constants, \( C_b \) and \( \beta_b \), for nine sets of \((\varepsilon_p, N_c)\) data have been extracted and these are tabulated in Table 1 [23]. Using these fitting constants, the \((\varepsilon_p, N_c)\) data were regenerated and these are depicted in Figure 6.

**Table 1:** Sn37Pb: Extracted Creep Fatigue Fitting Constants [23]

<table>
<thead>
<tr>
<th>Creep-fatigue coefficients</th>
<th>Temperature (K) at ( t_c = 1 ) sec</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>233K</td>
</tr>
<tr>
<td>( C_b            )</td>
<td>2.76</td>
</tr>
<tr>
<td>( \beta_b      )</td>
<td>0.775</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Creep-fatigue coefficients</th>
<th>Cycle time, ( t_c ) (s) at ( T=298 ) K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( 10^0 ) s</td>
</tr>
<tr>
<td>( C_b            )</td>
<td>2.22</td>
</tr>
<tr>
<td>( \beta_b      )</td>
<td>0.755</td>
</tr>
</tbody>
</table>
It is clear from Eq. (20) that a set of creep fatigue data, \((\varepsilon_p, N_{cf})\), can be transformed into a set of pure fatigue data, \((\varepsilon_{p,ref}, N_f)\), by transforming the magnitude of \(\varepsilon_p\) into \(\varepsilon_{p,ref}\) using the relation,

\[
\varepsilon_{p,ref} = \frac{\varepsilon_p}{c(\varepsilon_p,T,t_c)}.
\]  

(31)

Let \(c(\varepsilon_p,T,t_c) = 1 - X_k(\varepsilon_p) \eta_k(T,t_c)\), where \(X_k(\varepsilon_p) = a_k \varepsilon_p^b k\), the optimum values of \(C_o, \beta_o, a_k, b_k, \) and \(H/k, B_c, t_{c\infty}\) corresponding to the three cyclic parameter functions have been established through regressing the transformed fatigue data \((\varepsilon_{p,ref}, N_f)\) with the pure fatigue equation, \(\varepsilon_{p,ref} = C_o N_f^{-\beta_o}\). The optimum values are tabulated in Table 2 and completes with the relative magnitude of regression difference. The collapsed data of \((\varepsilon_{p,ref}, N_f)\) corresponding to the three cyclic parameter functions are depicted in Figure 7.

**Table 2: Sn37Pb: Fitting Constants for Creep Integrated Fatigue Equation Based on the Rate Equations of Sherby-Dorn, Larson-Miller, and Manson-Haferd**

<table>
<thead>
<tr>
<th>Rate equations</th>
<th>Fatigue coefficients</th>
<th>(\chi=a\varepsilon_p^b)</th>
<th>Fitting constant for (\eta(T,t_c))</th>
<th>Relative magnitude of regression residue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sherby-Dorn</td>
<td>1.85 0.740</td>
<td>8.40x10^8 6.93x10^-2</td>
<td>(H/k = 8.98x10^3)</td>
<td>3.4</td>
</tr>
<tr>
<td>Larson-Miller</td>
<td>6.58 0.806</td>
<td>1.17x10^-4 4.43x10^-2</td>
<td>(B_c = 4.39x10^7)</td>
<td>2.8</td>
</tr>
<tr>
<td>Manson-Haferd</td>
<td>3.75 0.773</td>
<td>-2.00x10^-1 5.00x10^-2</td>
<td>(t_{c\infty} = 2.34x10^7)</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 6: Sn37Pb: Regenerated Experimental Creep Fatigue Data

![Figure 6: Sn37Pb: Regenerated Experimental Creep Fatigue Data](image_url)
It is noted that the fractional fatigue capability function that is based on the Manson-Hafred parameter returns a much smaller magnitude of regression residue than the other two parameter functions. This is consistent with the reported superior description of creep rupture of metal alloys for the Manson-Hafred parameter over the other two parameters [17]. Indeed, the magnitude of the fatigue capacity, $C_o$, given by the Sherby-Dorn parameter function was impossibly low – lower than the magnitude of $C_b$ – while that given by the Larson-Miller parameter function appears to be unrealistically high.

IV. Discussions

The creep integrated fatigue equation integrates seamlessly the damages of creep and fatigue over the range from pure creep to pure fatigue. Comparing to the approach of the damage summation method, the creep integrated equation offers a more cohesive account for the combined damages of creep and fatigue. It does away with the challenging characterisation experiment that is required for the strain range partitioning method.

More valuably, the method can be generalised to model metal fatigue that is aggravated by a generalised damage driving force, $X$, whose rate of growth of damage may be expressed in the form

$$\dot{x} = g(\mu)h(T, t),$$  \hspace{1cm} (32)
where \( g(\mu) \) is a function of the magnitude of the damage driving parameter (for example, \( \mu \rightarrow \sigma \) in the case of creep being the damage driving force) while \( h(T, t) \) is a function of temperature and time. The rate function, Eq. (32), shall then be expressed into the form:

\[
\hat{g}(\mu) \hat{h}(T, t) = 1
\]

(33)
such as that shown in Eq. (23). The function \( \hat{g}(\mu) \hat{h}(T, t) \) is the damage function for the damage driving force \( X \). The damage force integrated fatigue equation is then given by

\[
\varepsilon_p = C_o c(\mu, T, t_c) N_x f^{-\beta_o},
\]

(34)

wherein

\[
c(\mu, T, t_c) = 1 - \hat{g}(\mu) \hat{h}(T, t_c).
\]

(35)
The magnitude of \( c(\mu, T, t_c) \) ranges from nil to unity corresponding to the case of pure fatigue and pure \( X \) damage, respectively. Let the damage function, \( \hat{g}(\mu) \), takes the form \( \hat{g}(\mu) = a \mu^b \), the fitting constants, \( C_o, \beta_o, a, b \), and that associated with \( \hat{h}(T, t_c) \) may be extracted through regression as illustrated in the previous section.

In case of a metal fatigue that is aggravated by \( n \) damage driving forces, Eq. (34) may be further generalised to integrate these damage forces, \( X_1, X_2, ..., X_n \), into the fatigue equation:

\[
\varepsilon_p = C_o c_1(\mu_1, T, t_c) c_2(\mu_2, T, t_c) ... c_n(\mu_n, T, t_c) N_x f^{-\beta_o},
\]

(36)

where

\[
c_j(\mu_j, T, t_c) = 1 - \hat{g}_j(\mu_j) \hat{h}_j(T, t_c), \quad j=1,2,\ldots,n,
\]

(37)
and \( \hat{g}_j(\mu_j) \) may be conveniently assumed to be a power law relation, \( a_j \mu_j^{b_j} \). In the absence of interaction between the damage forces, the coefficients, \( a_j \) and \( b_j \), of individual damaging force may be established individually by holding off other damaging forces.

It is worth mentioning that the Basquin equation, \( \sigma = C_o N_f^{-\beta} \), may be substituted for the Coffin-Manson equation in Eq. (34) in the case of an environmentally aggravated high cycle fatigue situation.

V. Conclusions

Creep fatigue analysis of solder joints in electronic assemblies has been presented. The condensed presentation comprised two major analyses: thermomechanical analysis and creep fatigue life modelling. The advanced analytical analysis can optimize the geometry of solder joints to minimise the magnitude of stresses in solder joints. This has led to the ideal geometry of stout hourglass for solder joints. The creep integrated fatigue equation integrates cohesively the damages of creep and fatigue over the range from pure creep to pure fatigue. The methodology can be generalised to model metal fatigue that is aggravated by multiple damaging forces.

References Références Referencias

3. IPC/JEDEC-J-STD-020F (2023), Moisture/Reflow Sensitivity Classification for Non-hermetic Surface Mount Devices (SMDs)


Landuse and Landcover Changes in Reservoir Catchments of Irrigation Dams in Northern Ghana

By Thomas Apusiga Adongo & Felix K. Abagale

Abstract- An assessment of landuse and landcover (LULC) patterns and changes at catchment level is crucial to planning and management of dam reservoirs. LULC changes over a 30-year period for 9 reservoir catchments in northern Ghana were assessed using a mixed-method approach involving GIS/remote sensing technique and key informant interviews. Four major LULC namely; cropland, water bodies, built-up land and open savannah woodlands were identified and classified from 1986, 1996, 2006 and 2016 LandSat TM images of the reservoir catchments. Substantial changes in LULC were observed in the reservoir catchments from 1986 to 2016, mainly through the conversion of large areas of closed and open savannah woodlands to cropland and built-up areas. Across all the catchments, cropland and built-up land increased significantly whilst water bodies, open savannah woodland and closed savannah woodland experienced a declined over the past 30-years.

Keywords: landuse and landcover changes, reservoir catchments, croplands, waterbodies, built-up areas, closed and open savannah woodlands.

GJRE-J Classification: LCC: GB980-2998

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Abstract- An assessment of landuse and landcover (LULC) patterns and changes at catchment level is crucial to planning and management of dams reservoirs. LULC changes over a 30-year period for 9 reservoir catchments in northern Ghana were assessed using a mixed-method approach involving GIS/remote sensing technique and key informant interviews. Four major LULC namely; cropland, water bodies, built-up land and open savannah woodlands were identified and classified from 1986, 1996, 2006 and 2016 LandSat TM images of the reservoir catchments. Substantial changes in LULC were observed in the reservoir catchments from 1986 to 2016, mainly through the conversion of large areas of closed and open savannah woodlands to cropland and built-up areas. Across all the catchments, cropland and built-up land increased significantly whilst water bodies, open savannah woodland and closed savannah woodland experienced a declined over the past 30-years. Between the years 1986 and 2016, cropland and built-up areas increased by 13.80 to 58.88% and 3.17 to 18.82% respectively, whereas water bodies and open savannah woodland decreased by 14.28 to 46.03% and 0.17 to 5.29% respectively. The driving factors of these changes have been noted as human population, farmland expansion, deforestation, lack of community involvement in the management of the catchments and lack of proper education on catchment management. The changes in LULC in the catchments could lead to dramatic changes in the catchment peak flows, increase in soil erosion, high sediment loads and sedimentation of the reservoirs. Good agricultural practices are necessary in the catchment management.

Keywords: landuse and landcover changes, reservoir catchments, croplands, waterbodies, built-up areas, closed and open savannah woodlands.

1. INTRODUCTION

Landuse and landcover (LULC) changes in reservoir catchments around the globe have significant environmental implications and consequences, which may include distresses in hydrological cycles, loss of biodiversity, increase in soil erosion, sediment loads and reservoir sedimentation (Lambin and Geist, 2006). Changes in LULC in a reservoir catchment can be categorized by the complex interaction of structural and behavioral factors associated with technological capacity, demand and social relations that affect both environmental capacity and the demand, along with the nature of the environment of interest (Verburg et al., 2004). Changes in LULC are primarily associated with anthropogenic activities such as deforestation, bush burning, urbanization, construction of dams and agriculture (Yigzaw and Hossain, 2016). Anthropogenic activities have been identified as the main cause of landuse/landcover changes and sedimentation in the Shiyang Reservoir in China with 43% of woodland areas converted into agricultural land (Zhou, 2002). Mzuza et al. (2017) reported that the Nkula Dam in the Middle Shire River Catchment in Malawi had been threatened with massive sedimentation and this was attributed to increased human population and agricultural activities in the reservoir catchment. In Ghana, a similar study conducted by Boakye et al. (2008) to assess the impact of landuse changes in the Barekese catchment on its associated reservoir revealed a loss in reservoir storage capacity of 45% due to sedimentation over a period of six years. The causes for the rapid rate of sedimentation of the reservoir were attributed to deforestation, population growth and lack of proper education of the communities in catchment management.

Increased demands on available resources mainly due to expanding population globally have led to the clearing of marginal lands for agricultural production and for settlement purposes. This has resulted in increased erosion, more rapid rates of sediment loading in reservoirs and reduced socio-economic benefits which they were constructed for (Mavima et al., 2011). In northern Ghana, the estimated mean annual soil loss in reservoir catchments ranged from 3.71 – 8.17 t/ha/yr and this could potentially contribute to sedimentation of their associated reservoirs (Adongo et al., 2019a). Spatial and temporal data on landuse and landcover changes is required to arrive at informed decisions in integrated water management (Mavima et al., 2011). LULC Change detection involves applying multi-temporal remote sensing information to analyze the historical effects of an occurrence quantitatively and thus helps in determining the changes associated with land cover and landuse properties with reference to the multi-temporal datasets (Ahmad, 2012; Seif and Mokarram, 2012).
In recent years, a variety of LULC change detection techniques and algorithms have been developed that make use of remotely sensed images. The most commonly used techniques include: Unsupervised classification, Supervised classification, Principal Component Analysis, Hybrid classification, Fuzzy classification, image overlay, classification comparisons of land cover statistics, change vector analysis, image rationing and the differencing of Normalized Difference Vegetation Index (NDVI) (Duadze, 2004). With proper understanding of the spatial and temporal variations occurring in a reservoir catchment over time and the interaction of the hydrological components of a reservoir catchment with each other, better water conservation strategies can be formulated (Ashraf, 2013). The question regarding information on landuse and landcover changes over time, and their driving forces in the reservoir catchments in northern Ghana are not known. Such knowledge is critical to the development of policies and action plans necessary for controlling sediment accumulation in reservoirs. Therefore, this study was carried out using GIS and Remote Sensing applications to analyze the extent of changes in nine (9) reservoir catchments over a period of 30 years in northern Ghana.

II. Materials and Methods

a) Study Area

The study was carried out in nine (9) reservoir catchments in northern Ghana as presented in Table 1 which also contains their principal characteristics and with Fig. 1 being the maps of the study sites.

Table 1: Study Reservoirs and Their Principal Characteristics

<table>
<thead>
<tr>
<th>Region</th>
<th>Northern</th>
<th>Upper East</th>
<th>Upper West</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir</td>
<td>Bontanga</td>
<td>Gambibgo</td>
<td>Vea</td>
</tr>
<tr>
<td></td>
<td>Golinga</td>
<td>Tono</td>
<td>Daffiama</td>
</tr>
<tr>
<td></td>
<td>Libga</td>
<td>Bolgatanga</td>
<td>Karni</td>
</tr>
<tr>
<td>District/ Municipality</td>
<td>Kumbungu</td>
<td>Kassena -</td>
<td>Lambu -</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nankana</td>
<td>ssie-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bongo</td>
<td>Karni</td>
</tr>
<tr>
<td>Location Coordinates</td>
<td>9° 57'N</td>
<td>10° 45'N</td>
<td>10° 27N</td>
</tr>
<tr>
<td></td>
<td>1° 02'W</td>
<td>0° 50'W</td>
<td>02° 34W</td>
</tr>
<tr>
<td></td>
<td>0° 57W</td>
<td>5° 10'W</td>
<td>02° 38W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9°59N</td>
<td>10° 52N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0° 85W</td>
<td>0° 51W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10° 52N</td>
<td>0° 51W</td>
</tr>
<tr>
<td>Catchment Area (km²)</td>
<td>165</td>
<td>1.70</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>53</td>
<td>650</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>136</td>
<td>141</td>
</tr>
<tr>
<td>Rainfall System</td>
<td>Uni-modal</td>
<td>Uni-modal</td>
<td>Uni-modal</td>
</tr>
<tr>
<td>Annual Mean (mm)</td>
<td>1,000 – 1,300</td>
<td>700 – 1,010</td>
<td>800 – 1,100</td>
</tr>
<tr>
<td>Duration (months)</td>
<td>5 – 6</td>
<td>5 – 6</td>
<td>5 – 6</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>Day</td>
<td>Night</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>33 – 39</td>
<td>23 – 28</td>
<td>36 – 55</td>
</tr>
<tr>
<td></td>
<td>Night</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>35 – 45</td>
<td></td>
<td>32.2</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>33 – 45</td>
<td></td>
<td>35 - 50</td>
</tr>
<tr>
<td>Relative Humidity (%)</td>
<td>Dry Season</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wet Season</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>Agro-ecological Zone</td>
<td>Guinea Savannah</td>
<td>Guinea/Sudan Savannah</td>
<td>Guinea Savannah</td>
</tr>
<tr>
<td>Geology</td>
<td>Precambrian basement rocks and Paleozoc rocks from the voltaian sedimentary basin</td>
<td>Metamorphic and igneous rocks with gneiss, granodiorite and sandstone</td>
<td>Precambrian, granite and metamorphic rocks</td>
</tr>
<tr>
<td>Soil Classes</td>
<td>Acrisols, plinthosols, planosols, luviosols, gleysols and fluvisols</td>
<td>Plinthosols, luviosols, vertisols, leptosols, lixisols, and fluvisols</td>
<td>Lixisols, fluvisols, leptosols, vertisols, acrisols and plinthosols</td>
</tr>
</tbody>
</table>

Adapted from Adongo et al. (2019a)
b) **Methodology**

The study used multi-temporal and multi-sensor Landsat satellite imageries to establish the landuse and landcover (LULC) changes in the study reservoir catchments for the years of 1986, 1996, 2006 and 2016. A summary of the flow chart of the methodology of LULC change detection analysis of the reservoir catchments is presented in Fig. 2.
The satellite images were derived from an open source Satellite Imagery Database from the United States Geological Survey (USGS) website. Detailed characteristics of the Landsat images of the various catchments is presented in Table 2.

Table 2: Characteristics of Landsat Images of the Reservoir Catchments

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Sensors</th>
<th>Date of Acquisition</th>
<th>Spatial Resolution (m)</th>
<th>Spectral Bands</th>
<th>Path/Row</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gambibgo, Tono</td>
<td>Landsat TM</td>
<td>05/10/1986</td>
<td>30 x 30</td>
<td>4,3,2</td>
<td>195/52</td>
<td>USGS</td>
</tr>
<tr>
<td></td>
<td>Landsat TM</td>
<td>05/10/1996</td>
<td>30 x 30</td>
<td>4,3,2</td>
<td>195/52</td>
<td>USGS</td>
</tr>
<tr>
<td></td>
<td>Landsat TM</td>
<td>05/10/2006</td>
<td>30 x 30</td>
<td>4,3,2</td>
<td>195/52</td>
<td>USGS</td>
</tr>
<tr>
<td></td>
<td>Landsat 8 OLI</td>
<td>05/10/2016</td>
<td>30 x 30</td>
<td>5,4,3</td>
<td>195/52</td>
<td>GloVis</td>
</tr>
<tr>
<td>Vea</td>
<td>Landsat TM</td>
<td>05/10/1986</td>
<td>30 x 30</td>
<td>4,3,2</td>
<td>194/52</td>
<td>USGS</td>
</tr>
<tr>
<td></td>
<td>Landsat TM</td>
<td>05/10/1996</td>
<td>30 x 30</td>
<td>4,3,2</td>
<td>194/53</td>
<td>USGS</td>
</tr>
<tr>
<td></td>
<td>Landsat TM</td>
<td>05/10/2006</td>
<td>30 x 30</td>
<td>4,3,2</td>
<td>194/53</td>
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</tr>
<tr>
<td></td>
<td>Landsat 8 OLI</td>
<td>05/10/2016</td>
<td>30 x 30</td>
<td>5,4,3</td>
<td>194/52</td>
<td>GloVis</td>
</tr>
<tr>
<td>Bontanga, Golinga, Libga</td>
<td>Landsat TM</td>
<td>05/10/1986</td>
<td>30 x 30</td>
<td>4,3,2</td>
<td>194/53</td>
<td>USGS</td>
</tr>
<tr>
<td></td>
<td>Landsat TM</td>
<td>05/10/1996</td>
<td>30 x 30</td>
<td>4,3,2</td>
<td>194/53</td>
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<tr>
<td></td>
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<td>4,3,2</td>
<td>194/53</td>
<td>USGS</td>
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<tr>
<td></td>
<td>Landsat 8 OLI</td>
<td>05/10/2016</td>
<td>30 x 30</td>
<td>5,4,3</td>
<td>195/53</td>
<td>GloVis</td>
</tr>
<tr>
<td>Daffiama, Karni, Sankana</td>
<td>Landsat TM</td>
<td>05/10/1986</td>
<td>30 x 30</td>
<td>4,3,2</td>
<td>195/53</td>
<td>USGS</td>
</tr>
<tr>
<td></td>
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<td>05/10/1996</td>
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<td>4,3,2</td>
<td>195/53</td>
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<tr>
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<td>Landsat TM</td>
<td>05/10/2006</td>
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<td>4,3,2</td>
<td>195/53</td>
<td>USGS</td>
</tr>
<tr>
<td></td>
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<td>05/10/2016</td>
<td>30 x 30</td>
<td>5,4,3</td>
<td>195/53</td>
<td>GloVis</td>
</tr>
</tbody>
</table>

TM – Thematic Mapper; OLI – Operational Land Image; USGS GloVis – United States Global Visualization Viewer

Two software, ERDAS Imagine version 10.4 and ArcGIS version 10.4 were used to process the satellite images for layer stacking, mosaicking, geo-referencing, subsetting and training of the images according to the Area of Interest (AOI). In ERDAS Imagine, image band combinations were manipulated from the default natural colour band combination in the image drape viewer to effectively identify different land use types in the study.
area, and the findings were later verified by ground truthing (gathered information/image material related to real features on the ground) to generate an appropriate training sample dataset for supervised classification. To improve the visual interpretability of the satellite data for a particular application, image enhancement was performed on all the acquired scenes. A classification scheme was then developed of which the following five (5) landuse and landcover classes were distinguished; cropland, water body, built-up land/bare land/rocky ground, closed savannah woodland and open savannah woodland. Description of the various LULC classification schemes used in this study is presented in Table 3.

Table 3: Description of Delineated Landuse and Landcover Classes of the Catchments

<table>
<thead>
<tr>
<th>Serial Number</th>
<th>Landuse/Landcover Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cropland</td>
<td>Lands used for the cultivation of crops, i.e, crop fields.</td>
</tr>
<tr>
<td>2</td>
<td>Waterbodies</td>
<td>Waterbodies in the catchment area that empty into the reservoirs. These include; streams, lakes, ponds and rivers.</td>
</tr>
<tr>
<td>3</td>
<td>Built-up land/rocky ground/bare land</td>
<td>Areas with intense infrastructural developments and exposed surfaces due to human activities or natural factors. These include; residential areas, industrial areas, commercial areas, recreational grounds, farmsteads, schools, lorry parks, roads and rocks. Bare land is land covered with sand or gravel. It has limited ability to support life and therefore uncultivated.</td>
</tr>
<tr>
<td>4</td>
<td>Closed savannah woodland</td>
<td>Thick forest lands, groves, thick plantations.</td>
</tr>
<tr>
<td>5</td>
<td>Open savannah woodland</td>
<td>Shrublands, grasslands and fallow lands.</td>
</tr>
</tbody>
</table>

Enhancement techniques were used together with classification techniques to extract features for the study reservoir catchments, locating areas and objects on the ground and deriving useful information from the images. Furthermore, use of enhancement techniques to visually interpret the images helped optimise the complementary capabilities of the processing. Classification was done for 1986, 1996, 2006 and 2016 images to identify the various LULC types and changes occurring over the years. Accuracy assessment of the classified imagery was performed to establish the level of accuracy of the classification. A non-parametric Cohen’s Kappa test was performed to measure the extent of classification accuracy. Cohen’s Kappa tries to measure the agreement between predefined producer-ratings and user assigned-ratings (Butt et al., 2015). It is computed using Equation 1 developed by Viera and Garrett (2005):

\[ K = \frac{P(A) - P(E)}{1 - P(E)} \quad (1) \]

Where: P (A) – Number of times the k raters agree and P (E) – Number of times the k raters are expected to agree only by chance. The P(A) and P(E) were generated in ArcGIS using the ground coordinates of the ground truth samples.

The classification comparison of LULC statistics method was used for the change detection analysis. This method was adapted because the study sought to determine quantitative changes in the areas of the various LULC categories. Using the post-classification procedure, the area statistics for each of the LULC classes was derived from the classifications of the images for each date (1986, 1996, 2006 and 2016) separately, using functions in the ERDAS-Imagine-Software 10.4. The areas covered by each LULC type for the various time intervals were compared. The percentage landuse and landcover change (% LULCC) at the catchments was computed using the formula developed by Lambin(2001) and presented in Equation 2.

\[ \% \text{LULCC} = \frac{\text{Observed Area Change}}{\text{Total Area of Catchment}} \times 100 \quad \ldots (2) \]

ArcGIS 10.4 was used for map composition as it increases the level of accuracy of the LULC change determined from the image.

c) Key-Informant Interviews

Key-informant interviews were conducted with key stakeholders such as local traditional leaders in the communities of the catchments and the management of the irrigation dams from January to March, 2018. The key-informant interviews were conducted so as to augment the data that was obtained from Landsat images and field measurements. A total of 81 respondents (9 from each catchment) were interviewed. To ensure the acquisition of comprehensive information, the respondents were people of age 45 to 60 years, who are longtime residents (i.e. > 25 years) of the selected communities. They were selected based on their experience and knowledge on landuse and landcover changes in the catchments.
III. Results and Discussion

a) Areal Extent of Landuse and Landcover Classes in the Reservoir Catchments

Four (4) major landuse/landcover (LULC) categories namely; cropland, waterbodies, built-up land and open savannah woodland were identified and classified in the reservoir catchments, except Tono catchment where closed savannah woodland was identified as the fifth (5th) major LULC class (Figure 3 and Table 4). The LULC maps of the catchments clearly showed that there were variations in the LULC types in the last 30 years (1986-2016).

In 1986, except the Tono catchment, open savannah woodland was the predominant LULC class, occupying an area of 45.99% at Bontanga to 80.72% at Golinga. At Tono catchment, the predominant LULC was closed savannah woodland with a coverage area of 233.89 ha (35.98%), followed by open savannah woodland with area occupancy of 30.56%. Except Tono catchment, the second most predominant class was cropland with coverage area of 15.57% at Golinga to 45.57% at Bontanga, followed by built-up area with a coverage of 1.7% at Bontanga to 8.24% at Gambibgo. Across all the catchments, water body occupied the least area with values ranging from 0.44% at Sankana to 6.75% at Vea (Table 4).

The 1996 Landsat images of the catchments showed a reduction of LULC change compared with 1986 for the different LULC classes, except cropland and built-up areas. Open savannah woodland occupied a significant portion of the catchments with an area coverage of 39.94% at Gambibgo to 66.55% at Golinga, followed by cropland which was randomly distributed within the catchments with an area of 27.74% at Tono to 52.78% at Bontanga. Built-up area occupied a minor area of 2.39% at Bontanga to 15.29% at Gambibgo. Water bodies occupied the least area of 0.40% at Sankana to 5.85% at Vea (Table 4).

From the 2006 image classification it was noted that both water bodies and open savannah woodland were reduced from their coverage in 1996 (Table 4). Water bodies were reduced by 0.05% at Sankana to 2.35% at Gambibgo whilst open savannah woodland reduced by 5.75% at Vea to 18.94% at Golinga. Closed savannah woodland also reduced by 8.37% at Tono. On the other hand, cropland coverage increased by 3.11% at Tono to 18.72% at Golinga, and built-up areas coverage also increased by 0.36% at Golinga to 9.41% at Gambibgo catchment.

The 2016 Landsat map showed substantial changes relative to the previous 20-year period with croplands occupying the greatest area of the catchments with values ranging from 37.82% at Tono to 74.45% at Golinga, followed by open savannah woodland with 17.68% at Golinga to 33.63% at Tono catchment. However, at the Libga and Gambibgo catchments, built-up areas were noted to be the second largest LULC class occupying 22.87% and 37.06% of their areas respectively. Patches of closed savannah woodland with a total area coverage of 13.84% were found in the northern zone of the Tono catchment. Except Libga and Gambibgo catchments, built-up areas occupied an area of 4.99% at Bontanga to 18.62% at Daffiama catchment. The remaining parts of the catchments were composed of water bodies with the least area of 0.27% at Sankana to 4.49% at Bontanga (Table 4).
LAND USE AND LANDCOVER CHANGES IN RESERVOIR CATCHMENTS OF IRRIGATION DAMS IN NORTHERN GHANA
Fig. 3: Landuse/Landcover Landsat Images of Study Reservoir Catchments for 1986, 1996, 2006 and 2016

Table 4: Areal Extent of Different Landuse/Landcover Classes in the Study Reservoir Catchments from the Year 1986 to 2016

<table>
<thead>
<tr>
<th>Landuse/Landcover Class</th>
<th>Bontanga Catchment</th>
<th>Golinga Catchment</th>
<th>Libga Catchment</th>
<th>Gambibgo Catchment</th>
<th>Tono Catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland</td>
<td>75.19</td>
<td>67.27</td>
<td>97.67</td>
<td>111.00</td>
<td>8.25</td>
</tr>
<tr>
<td>Built-up land</td>
<td>2.80</td>
<td>4.99</td>
<td>3.55</td>
<td>4.99</td>
<td>1.12</td>
</tr>
<tr>
<td>Water body</td>
<td>11.13</td>
<td>11.11</td>
<td>3.77</td>
<td>7.11</td>
<td>2.11</td>
</tr>
<tr>
<td>Open SW</td>
<td>75.88</td>
<td>17.68</td>
<td>52.71</td>
<td>38.36</td>
<td>42.78</td>
</tr>
<tr>
<td>Closed SW</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.26</td>
</tr>
<tr>
<td>Total</td>
<td>165.00</td>
<td>100.00</td>
<td>165.00</td>
<td>100.00</td>
<td>53.00</td>
</tr>
</tbody>
</table>
b) Landuse and Landcover Classification Accuracy Assessment for 2016

According to Owojori and Xie (2005), it is crucial to perform accuracy assessment for LULC classification if the classification data are to be used for change detection analysis. Accuracy assessment establishes the level of accuracy of the classification. Coppin and Bauer (1996) reported that a classification accuracy of 0 - 69% indicates low accuracy whereas 70 – 100% indicates high accuracy, and a kappa coefficient < 0.5 and > 0.5 indicates low and high accuracies respectively. As presented in Table 5, an accuracy assessment elaborated for the 2016 image classification revealed an overall classification accuracy of 80% and overall Kappa coefficient (statistic) of 0.75. The highest user accuracy of all the LULC classes was obtained for water bodies of 92.5% whilst cropland recorded the lowest user accuracy of 72.2%. Also, for producer accuracies, water bodies and cropland recorded the highest and lowest values of 100% and 64.4% respectively. Based on the assertion of Coppin and Bauer (1996), the classification accuracy for the study was high. In a similar study in Ghana, Antwi-Agyei et al. (2019) obtained high overall classification accuracy of 77.56% and overall Kappa statistic of 0.77 in Owabi reservoir catchment.
Table 5: Classification Accuracy Assessment for the Year 2016

<table>
<thead>
<tr>
<th>LULC Class</th>
<th>Reference Totals</th>
<th>Classified Totals</th>
<th>Correct Number</th>
<th>Producer's Accuracy (%)</th>
<th>User's Accuracy (%)</th>
<th>Kappa Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland</td>
<td>45</td>
<td>40</td>
<td>29</td>
<td>64.4</td>
<td>72.2</td>
<td>0.68</td>
</tr>
<tr>
<td>Built-up land</td>
<td>34</td>
<td>40</td>
<td>30</td>
<td>88.2</td>
<td>75.0</td>
<td>0.71</td>
</tr>
<tr>
<td>Water body</td>
<td>37</td>
<td>40</td>
<td>37</td>
<td>100.0</td>
<td>92.5</td>
<td>0.87</td>
</tr>
<tr>
<td>Open SW</td>
<td>43</td>
<td>40</td>
<td>35</td>
<td>81.4</td>
<td>87.5</td>
<td>0.82</td>
</tr>
<tr>
<td>Closed SW</td>
<td>41</td>
<td>40</td>
<td>29</td>
<td>70.7</td>
<td>72.5</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>200</strong></td>
<td><strong>200</strong></td>
<td><strong>160</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall classification accuracy = 80.0 % and overall kappa coefficient (statistic) = 0.75

LULC = Landuse and Landcover; SW = Savannah woodland

c) Landuse and Landcover Changes Detection Analysis with the Reservoir Catchments from 1986 to 2016

Substantial changes in LULC categories were observed to have taken place in the reservoir catchments from 1986 to 2016, mainly through the conversion of large areas of closed and open savannah woodlands to cropland and built-up areas. Across all the catchments, cropland and built-up land saw a consistent and significant increase whilst water bodies, open savannah woodland and closed savannah woodland experienced a decline over the past 30-years (Table 6). Between 1986 and 1996, cropland increased by 3.56% at Karni to 18.24% at Gambibgo. Also, built-up land increased by 0.47% at Karni to 7.06% at Gambibgo. Water bodies decreased by 0.04% at Sankana to 8.82% at Gambibgo whilst open savannah woodland declined by 5.75% at Vea to 16.48% at Libga. At Tono catchment, however, open savannah woodland increased by 5.59% and closed savannah woodland saw a decrease of 10.57% to other LULC classes.

The study also found that between 1996 and 2006, cropland increased by 3.11% at Tono catchment to 18.72% at Golinga catchment, whilst built-up land increased by 0.36% at Golinga to 9.41% at Gambibgo catchment. However, water bodies recorded a marginal declined by 0.05% at Sankana catchment to 2.35% at Gambibgo catchment. Open savannah woodland experienced a declined by 5.75% at Vea catchment to 18.94% at Golinga catchment as presented in Table 6.

Between 2006 and 2016, cropland significantly increased by 2.58% at Libga catchment to 26.59% at Golinga catchment, whilst at Gambibgo catchment, it decreased by 5.88% probably to settlement built-up areas. Also, built-up land increased by 1.44% at Sankana catchment to 12.35% at Gambibgo catchment. However, water bodies decreased marginally by 0.08% at Golinga and Sankana catchments to very high of 4.12% at Gambibgo catchment. Open savannah woodland also saw a decline of 2.21% at Tono catchment to 18.94% at Golinga catchment as presented in Table 6. It was also noted that the closed savannah woodland at Tono catchment decreased by 5.60% to probably other LULC categories such as cropland and built-up land.

Table 6: Landuse and Landcover Changes of the Study Reservoir Catchments

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Bontanga</th>
<th>Golinga</th>
<th>Libga</th>
<th>Gambibgo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built-up land</td>
<td>1.14</td>
<td>0.69</td>
<td>1.92</td>
<td>1.16</td>
</tr>
<tr>
<td>Water body</td>
<td>-1.46</td>
<td>-0.88</td>
<td>-0.91</td>
<td>-0.55</td>
</tr>
<tr>
<td>Closed SW</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Catchment</td>
<td>Tono</td>
<td>Vea</td>
<td>Tono</td>
<td>Vea</td>
</tr>
<tr>
<td>Cropland</td>
<td>24.15</td>
<td>3.72</td>
<td>20.23</td>
<td>3.11</td>
</tr>
</tbody>
</table>

Overall classification accuracy = 80.0 % and overall kappa coefficient (statistic) = 0.75
The driving forces for LULC changes in the study reservoir catchments resulted from direct and indirect causes. The direct causes constituted human activities that originated from intended landuse and directly affect LULC. The results from key informant interviews in communities located in the catchments during the study indicated that there is a significant evidence of LULC change resulting from farmland expansion (37%); clearing trees for fuelwood and charcoal for domestic consumption and for sale (24%); clearing of forest for human settlement development (20%); wildfires (15%) and illegal harvesting of forests for timber production (4%) (Fig. 4). The most significant indirect drivers behind the LULC changes noticed on the catchments were related to human population increase (demographic factors) (43%); economic, technological and cultural factors among the land ownership (27%); climate variability in the catchment (19%) and institutional factors (11%) (Fig. 5).

Fig. 4: Direct Causes of LULC Changes in Reservoir Catchments
The increased in human population in the catchments over the years has accelerated the demand for agricultural land and settlement development which had led to deforestation and thus reduced the forest cover. The results of the study showed a massive reduction in forested areas in the Tono catchment which was noted to correspond to the results of other studies suggesting that forest areas in Ghana have undergone massive reduction (Adade and Oppelt, 2019). Census data showed that between 1986 and 2016, human population in the five (5) regions of northern Ghana increased with an average growth rate of 2.1% per annum (GSS, 2014), implying an expansion of agricultural land and built-up areas to meet demand.

According to Attua and Fisher (2011) and Antwi et al. (2014), human population growth is widely recognized as a main driver of environmental and LULC change, especially in developing countries. The changes observed in the study reservoir catchments are consistent with those observed in many studies conducted at national and regional levels in Ghana such as Antwi et al. (2014), Kleeman et al. (2017) Asubonteng et al. (2018), Shoyama et al. (2018), Adade and Oppelt (2019) and Antwi-Agyei et al. (2019). For example, using a mixed-method approach, Kleeman et al. (2017) identified population growth as a major driver of LULC changes in Ghana’s Upper East Region. Various anthropogenic activities, including agriculture, have led to encroachment of human settlements on forest lands, with devastating consequences for biodiversity (Antwi et al., 2014). In Namibia and Kenya, studies have identified agricultural expansion, human population growth increase and illegal logging as the key drivers of landuse and landcover changes in catchments, with serious debilitating effects on their associated reservoirs and peoples’ livelihood activities (Ogechi and Waithaka, 2017). Overall, a large population entails a higher demand for fuelwood and conversion of more agricultural land to human settlements to meet the growing feeding needs (Kassa et al., 2017). With the projected steady increase of the global human population at a rate of 1.1% per annum (UN-DESA, 2017), the fragile reservoir catchments of northern Ghana will without doubt continue to suffer from anthropogenic pressures.

e) Potential Consequences of the Landuse and Landcover Changes in the Study Catchments

The trend of landuse and landcover changes detected in the study has shown general conversion of the closed and open savannah woodland to cropland and built-up and open areas. These conversions have potential consequences on the catchments’ characteristics and hydrology. According to Weiss and Milich (1997), landcover is a function of rainfall regime, soil conditions and geomorphology. This indicates that the conversion of the closed and open savannah woodlands to croplands, grasslands and settlements would definitely lead to changes in the soil conditions and the geomorphology of the catchments.

Similarly, Costa et al. (2003) reported that the conversion of forest to grassland disrupts the hydrological cycle of the catchment by altering the balance between rainfall and evaporation and, consequently, the runoff response of the area. With less litter due to wildfires and clear/burn practices in the catchments, the capacity of surface detention is decreased, and a greater proportion of the rainfall runs off as overland flow. The shift from sub-surface flow to overland storm flows accompanying deforestation, expansion of croplands and built-up areas may produce dramatic changes in the catchment peak flows as well and make the land more vulnerable to erosion leading to sedimentation of the reservoirs. Adongo et al. (2019b) reported that the estimated mean annual soil loss in the reservoir catchments ranged from 3.71 to 8.17 t/ha/yr. Lack of enforcement of environmental by-laws by the local rural district council regarding deforestation has led to uncontrolled cutting down of trees within the catchment and much of the woodland has now become grassland area.
Also, Boakye et al. (2008) noted that practices relating to farming and urbanization such as construction and soil compaction during logging can reduce the infiltration capacity of the soil and in turn the flow of water through the soil profile in Barekese catchment in Ghana. Moreover, the increase in farming activities in the catchments coupled with increasing runoff could also increase erosion and sedimentation of the reservoirs thus, transporting more sediment into the river leading to the gradual sedimentation of the reservoirs. Therefore, these LULC changes detected could be the cause of the sedimentation in the reservoirs at a rate of 0.26 to 0.91%/yr, as reported by Adongo et al. (2019). A similar study conducted in Ghana noted a similar trend whereby sedimentation of reservoirs was mainly attributed to deforestation and lack of proper education of the communities in catchment management (Boakye et al., 2008).

IV. Conclusions

The study identified and classified cropland, water bodies, built-up land, open savannah woodland and closed savannah woodland as the five major landuse and landcover categories in the various sites. Over the 30 year period, substantial areas of closed and open savannah woodlands were noted to have been converted into croplands and built-up areas with water bodies declining mainly due to anthropogenic activities. Closed savannah woodland was only identified in the Tono reservoir catchment although its area decreased overtime.

Farmland expansion, domestic and commercial fuelwood and charcoal production, construction activities, wildfires/bushfires, and illegal harvesting of forests for timber production were observed as casual factors for these changes. These factors were influenced by human population increase, economic, climate variability in the catchment, etc. These changes observed in the various catchments have an effect on catchment hydrological characteristics thus affecting water flows and increasing the level of vulnerability to erosion and its attendant effect on reservoir sedimentation. Strategies such as afforestation, ban on illegal harvesting of forest products, etc and involving local communities for effective and sustainable management of the catchments to reduce the effect of landuse and landcover change on catchment characteristics are recommended.

References


Evolution of the use of Nanoparticles in Cancer Diagnosis and Treatment

By Camila Andrea Gualdría Sandoval, Esperanza del Pilar Infante Luna & Luz Helena Camargo Casallas

Abstract- The use of nanoparticles in the health area is a research topic that has been increasing in recent years, from that perspective this work focused on making a characterization of nanoparticles, their evolution and interaction with blood, aspect addressed through the description of the biomagnetic fluid, focusing on characteristics such as viscosity and geometry. Also, the evolution of the applications or techniques in which nanoparticles have been used is presented, focusing the review on cancer treatments, for which the four progressive generations of this research field were considered, as well as the use of nanoparticles in diagnostic imaging. Finally, some fields of implementation and study in Colombia were identified. The review carried out allows concluding that the evolution of the use of nanoparticles.

Keywords: biomagnetic fluid, nanoparticles, magnetic nanoparticles, SPIONs

GJRE-J Classification: FOR Code: 0903

Strictly as per the compliance and regulations of:
Evolution of the use of Nanoparticles in Cancer Diagnosis and Treatment

Camila Andrea Gualdría Sandoval, Esperanza del Pilar Infante Luna & Luz Helena Camargo Casallas

Abstract - The use of nanoparticles in the health area is a research topic that has been increasing in recent years, from that perspective this work focused on making a characterization of nanoparticles, their evolution and interaction with blood, aspect addressed through the description of the biomagnetic fluid, focusing on characteristics such as viscosity and geometry. Also, the evolution of the applications or techniques in which nanoparticles have been used is presented, focusing the review on cancer treatments, for which the four progressive generations of this research field were considered, as well as the use of nanoparticles in diagnostic imaging. Finally, some fields of implementation and study in Colombia were identified. The review carried out allows concluding that the evolution of the use of nanoparticles. Keywords: biomagnetic fluid, nanoparticles, magnetic nanoparticles, SPIONS.

1. Introduction

The term nanotechnology refers to a multidisciplinary field that deals with the research, design, synthesis, application of materials and functional systems by controlling substances at the nanometer level. The interest of nanotechnology is not only to manipulate matter on a small scale, but also to study the unique physical and chemical properties of nanostructures (e.g., surface properties, electrical conductivity and magnetic properties). In recent years, nanotechnology has had a major impact in areas such as biology and medicine (Rojas, Aguado, & González, 2016). With the aim of advancing in this field, a bibliographic review was carried out, oriented towards three topics: characterizing nanoparticles (np) and their evolution; describing the medium in which they move and therefore their interaction with it, and identifying the applications or techniques of nanotechnology in health sciences, specifically in cancer treatments (tumors), and the obtaining of diagnostic images through methods that use nanoscopic contrast agents or markers.

II. Characterization, Description and Evolution of the NP

The np are particles with dimensions of the order of 1 nm = 1x10^-9 m, which facilitates their application to different fields of nanotechnology, in medicine for example, they are used for the purpose of monitoring, control, construction or repair, defending or improving the human biological system at the molecular level (Wakaskar, 2018). Some of the np used in cancer treatments have been dentrimers, being np with three-dimensional tree-like structures in the range of 1-100 nm, they can host a variety of carrier molecules, both hydrophobic and hydrophilic and are useful delivery agents for genes, drugs and anticancer agents; thanks to their size and geometry they can be specifically controlled in groups, in order to possess pre-designed and specific physical and chemical properties (Alfonso & Casado, 2016).

On the other hand, micelles are hydrophobic spherical structures that are grouped to form the central core of the sphere in a liquid environment (Haley & Frenkel, 2008), so they are useful for the administration of water-insoluble drugs with sizes in the range of 10 - 50 nm (Urrejola et al., 2018). Nanospheres, on the other hand, are spherical structures composed of a matrix system where the surface can be modified by adding polymers and also biological materials, have a size in the range of 10 - 100 nm (Haley & Frenkel, 2008). From the perspective of their use as carriers, nanocapsules are vesicular systems with a central cavity or core to which it is possible to confine a drug, their size is in the range of 10 - 500 nm (Chávez, Olvera, Ganem, & Quintanar, 2002). Finally, we find the magnetic ones, on which we will go deeper, because their characteristics have made possible advances in the transport through the blood as a biomagnetic fluid.

a) Magnetic Nanoparticles (MNP)

They are np that are iron-based, therefore they can be manipulated by employing an external magnetic field (B) (Avval et al., 2020). Magnetite (Fe3O4) is a black ferromagnetic iron oxide of Fe(II) and Fe(III), which has been the most studied, due to the potential to act as an electron donor (Mohammed, Gomaa, Ragab, & Zhu, 2017).

b) Ferrofluids

When talking about ferrofluids, we refer to a colloidal dispersion made by a special multidomain particles based on iron oxide and iron hydroxide by a wet chemical method, which facilitates the steering capability under the influence of a B (Lübke, Bergemann, Riess, et al., 1996). Additionally, these colloidal magnetic np have unique surface properties.
that allow biocompatibility and biodegradability in addition to having minimal toxicity, they are suitable as drug-delivery vehicles that have excellent magnetic saturation (Liu, Xu, Wang, & Ke, 2008).

c) Superparamagnetic

They are a unique type of MNP, because they have many desirable properties, from the point of view of biomedical applications, such as: biocompatibility, biodegradability and ease of synthesis, to which we must add their superparamagnetic nature. On the other hand, they do not produce hysteresis, since they leave a zero residual magnetization after an external B is removed, this feature helps to prevent coagulation, so compared to other MNP, it reduces the possibility of agglomeration in the body (Mohammed, Gomaa, Ragab, & Zhu, 2017).

The size of these particles influences both their physicochemical and pharmacokinetic properties, so two groups are classified: Spions: (superparamagnetic iron oxides) are np that in particular are generally based on inorganic iron oxide coated with hydrophilic polymers, whose size is larger than 50 nm (including the coating). USpions: (ultra-small superparamagnetic iron oxides) are np that have a size smaller than 50 nm, being blood pooling agents they could be used for perfusion imaging enabling the diagnosis of cerebral or myocardial ischemic diseases (Zhang et al., 2020).

III. CHARACTERIZATION AND INTERACTION OF THE ENVIRONMENT

Currently there is a field of research associated with the interaction of B with living beings, and in particular it has gained relevance in nanomedicine, from this perspective we can consider two basic areas: magnetobiology and biomagnetism. The former deals with the effects produced by magnetic fields on organisms, ranging from the orientation capacity of some animals, to the controversial damage to health caused by exposure to low-frequency electromagnetic waves. Biomagnetism, on the other hand, focuses on the study of the B associated to the organism itself, in particular we refer to the biomagnetic fluid, which is found in organisms and reacts to the presence of a B. The results of these experimental fields are useful to obtain information that does not allow us to understand biophysical systems, to implement new clinical diagnostic techniques and to create new therapies centered on the use of np (Sosa, Alvarado, & Gonz, 2002).

a) Blood as a Transport Medium for Nanoparticle

The various applications of np as a means of transporting drugs or contrast chemicals, have led researchers to deepen both the knowledge of the blood, as the fluid through which these particles move, the interaction with the components thereof, and the incidence of external magnetic fields applied, in this sense, Bose & Banerjee, (2015) mention measurements made to estimate the magnetic susceptibility of blood and reported that this is between 3.5 X 10^-6 and 6.6 X 10^-7 for venous and arterial blood, respectively, also Bartoszek & Drzazga, (1999) show an experimental study of the magnetic anisotropy of blood cells at a B of up to 1.8 T for a temperature range between 75 - 295 K, employing torsional magnetometry.

Ichioka & Ueno, (2000) conducted in vivo experiments using rats as subjects, which were subjected to magnetic fields of 8 T, showing a reduction in blood flow and temperature of the animal. In the same direction, the in vitro experiments conducted by Haik, Pai & Chen (1999), in which they used human blood samples subjected locally to a B of the same intensity, reduced by 30%, additionally established that as the biofluid enters and exits the gradient of B, in relation to the biomagnetic flux in narrow channels, Tzirtzilakis in 2005 found that these are affected by a constant and local B (Bose & Banerjee, 2015).

b) Simulating Biomagnetic Fluid (Blood)

Liu, Zhu, Rao, Clausen & Aidun, (2018) simulate the biortransport of np under a complex cell flow environment using a multiscale method based on the Lattice Boltzmann method (LBM), the basic components of which include liquid-phase LBM processing, the red blood cell spectrum linkage method (SLM), and the Langevin dynamics (LD) method to capture pauses of np motion. In addition, extensive bidirectional coupling schemes are established to capture precise interactions between each component and thus simulate np transport in cellular blood flow with high efficiency.

In turn, Lee, Ferrari & Decuzzi, (2009) present a general mathematical model to predict the transport behavior of particles with different physical properties: size (nano-microparticles) and shape, as well as the material in which they are immersed, considering a linear laminar flow. Their results show that non-spherical particles, under the concurrent action of inertial and hydrodynamic forces, can deflect laterally, an effect known as hydrodynamic margination, increasing the probability of interaction with the wall surface. Thus, in blood, np will periodically oscillate around their trajectory, thus reducing their distance from the vessel wall, while the particles may actually separate with a net lateral deflection.

On the other hand, Duncan & Bevan, (2015) generated a Monte Carlo simulation, measuring the net interactions between np “decorated” by ligands, which possess distinct chemical structures, providing multiple interactions in self-assembly, and membrane proteins on the surfaces of healthy and diseased cells. From their analysis, they identify that these ligand-functionalized np are able to selectively bind to populations of diseased cells rather than healthy cells, proving attractive for
improving the efficacy of drug therapies by using lower affinity ligands to target cancer cells with targeted membrane proteins.

Along the same lines, Müller, Fedosov & Gompper, (2014) performed simulations and attempted to study the marginal characteristics of carriers of different shapes and sizes using mesoscopic hydrodynamic simulations to explain the related physical mechanisms, finding that the properties of particle edges increase with increasing carrier size. The above results lead to the conclusion that addressing the various problems associated with drug delivery is a complex issue; its solution requires an interdisciplinary effort, including in vitro and in vivo experiments and realistic numerical simulations.

c) Viscosity

Blood viscosity and plasma viscosity are the best known parameters characterizing the properties of blood flow. Haik, Pai & Chen, (2001) conduct an investigation on the behavior of viscosity due to magnetic discharges in human blood, for which they carried out flow experiments on oxygenated blood in vitro and which is subjected to a B of up to 10 T. Additionally, they use a mathematical model to simulate biomagnetic fluid dynamics under similar conditions, which allows them to identify that the magnetization action will introduce a rotational motion to orient the magnetic fluid particles with the B (Afkhami & Renardy, 2017); however, the behavior and characteristics of the blood are unique to each patient. As a complement to the aforementioned computational experiments, Rukshin, Mohrenweiser, Yue & Afkhami, (2017) proposed a mathematical model describing the behavior of equations to visualize particle trajectories and calculate capture rates to assess the impact of various physical conditions on the success of magnetic drug targeting.

d) Geometry of the Medium

Another element to take into account in the characterization of the medium is the geometry, muscle arteries have three major geometrical differences with capillaries, for example in microvessels, the anti-slip boundary condition reduces the velocity of blood near the wall relative to the centerline and improves the ability to trap particles by weaker magnetic force due to lower resistance compared to millimeter vessels (Avilés et al., 2005). In this case, the force required is well below the maximum allowable exposure, however, due to the higher blood flow rate in muscles and blood vessels, the particles require a higher magnetic force to resist the “tenacity” that occurs in the opposite direction of particle motion.

IV. Evolution of Applications in Cancer Treatments, using NP

Cancer is a disease in which the cells of the human body acquire the ability to divide and multiply uncontrollably (Sharma, Sharma, Punj, & Priya, 2019), this condition acquired by the diseased cells through mutations of the genome, as the cancer cells divide, leads to the fact that the new cells will inherit the same growth capacity and increase the number of cancer cells (Miller, 2018). The treatments for this disease are diverse and in any case, side effects must be considered, therefore, targeted treatments are an important option for patients. In this sense, the evolution in the use of np is presented, which is approached through four generations, identifying the main investigations and their results.

a) First Generation

The first experiment was performed "in vivo" by Lübbe et al, (1996), who developed a magnetic fluid to which drugs, cytokines and other molecules can chemically bind to allow these agents to be directed into an organism by an external high-energy B. They used male rats and mice, kept in a controlled environment. For which they used male rats and mice, kept in a controlled environment. For the design of the external B, using high-energy permanent magnets made of rare earths (neodymium), they consisted of disks or blocks with variable thickness, configured in the shape of a column or a block (see Figure 1). In this way, the magnets could be arranged more closely around the individual tumor configuration, with a B between 0.2 - 0.5 T (depending on tumor size). They tested two forms of therapy with the magnetic fluid: treatment of tumors by mechanical occlusion with the ferrofluid in high concentrations; and magnetic therapy, using small amounts of the ferrofluid as a drug carrier vehicle, which allowed epirubicin to be concentrated locally in the tumors.

The first part of the study focused on tolerance to ferrofluid and magnetically bound epirubicin. The results show that hematological and blood chemistry values did not change from baseline after injection of different amounts of ferrofluid. On the other hand, epirubicin caused changes in hematological parameters. Histological data showed that the magnetic particles accumulated in the liver and spleen, without causing significant hepatosplenomegaly, the latter two results were within predicted. After the sixth week of observation, one animal in each high-dose group died, possibly due to cardiovascular failure caused by sepsis. In those groups in which the highdose epirubicin was administered, the animals died quickly; in the low-dose groups, they died somewhat later, around 4 - 6 weeks. In all other groups, including those receiving low levels of epirubicin, the animals survived the observation
period (Lübbe, Bergemann, Huhnt, Fricke, & Riess, 1996).

The second part of this investigation focused on the mechanical embolization by the ferrofluid after its injection and concentration in the tumor by means of an external B, regardless of the type of tumor, there was a rapid and constant decrease in tumor volume within 14 days after treatment. It was impossible to reproduce this tumor response in the animals given only epirubicin, although the tumors responded to the high dose of this drug, this was only for a brief period and most of the animals in this group died shortly thereafter.

Subsequent experiments by Lübbe led to the conclusion that magnetic fluid is a good agent to decrease tumor volume and with further studies, it can be used in different forms of local cancer treatment in conjunction with high-energy magnetic fields, avoiding mortality of the subject (Lübbe, Bergemann, Brock, & McClure, 1999).

**Fig. 1:** Graphic Illustration of Placement of Rare Earth Magnets in Block form on the Tumor to be Treated

Thus, in the second experiment, Lübbe et al., (1999) chose their subjects with an eligibility criterion among them, seven patients with breast cancer, two with chondrosarcoma, two with parotid squamous cell carcinoma, one with Ewing's sarcoma and two with malignant tumor; with a life expectancy of at least three months and renal preservation. Continuing their line of research, they employed anticancer drugs that would reversibly bind to magnetic fluids, which were focused on locally advanced tumors through a B disposed on the tumor surface outside the body.

They tested for magnetite concentration in the tumor, and 10 of the 14 patients, had intact skin covering the tumors, the other four showed wound healing and open superficial wounds. In the first four cases, since the B will obscure the shape of the magnetic block attached to the tumor, it is easy to observe magnetite absorption into the tumor, this discoloration lasted for 24 - 36 hours and then disappeared completely, these areas were not locally toxic and ensured that the discoloration could not be removed to rule out the possibility of iron deposition from the magnetic lumps in the superficial layer of the skin. So the targeted magnetic drug with epirubicin was well tolerated and mild tumor reductions were achieved at day 10 and some small responses at day 40 (Lübbe et al., 1999) (Lübbe, Bergemann, Riess, et al., 1996).

**b) Second Generation**

Based on the results described above, Alexiou et al. (2000) used mitoxantrone-linked ferrofluid (FF-MTX) to treat rabbits with squamous cell carcinoma and concentrated it under a B. When the tumor reaches a volume of 3500 mm³, FF-MTX is injected intra-arterially or intravenously. When an external B is focused on the tumor, it is activated by an electromagnet with a maximum flux density of 1.7 T, producing a non-uniform B, both in direction and magnitude, a feature that is crucial for the use of magnetic drugs. Magnetic drug targeting is a means of keeping the chemotherapeutic agent at the desired site of activity, thus increasing efficacy and decreasing systemic toxicity.

Only when the MTX dose was increased to 75% and 100%, tumor remission was observed, but this resulted in severe side effects (hair loss, ulcers and leukopenia). However, this “magnetically targeted drug” provides a unique opportunity to locally treat malignant tumors without systemic toxicity. In addition, it is possible to use these magnetic particles as "carrier systems" for various anticancer agents such as radionuclides, antibodies and cancer-specific genes (Alexiou et al., 2002).

**c) Third Generation**

Under another line of research, Gitter & Odenbac (2011) presented experimental results based on systematic “in vitro” quantitative measurements of a tube model simulating a Y-branched artery, in which they conclude that the success of particle orientation towards branching depends largely on the crossing point and the magnetic force at the site, elements that as previously mentioned must be evaluated.

For their part, Krukemeyer, Krenn, Jakobs & Wagner, (2011) performed a verification method on the effectiveness of cytostatic drugs coupled to ferromagnetic np and extracorporeal magnets, using 42 adult rats that were transfected with rhabdomyosarcoma. In the biodistribution assay, concentrations of mitoxantrone iron oxide and conventional mitoxantrone with and without 0.6 T magnets were measured in vitro in plasma and tumor tissue for one and two doses. During magnetic drug treatment, iron particles are rapidly removed and remain in the area where the tumor remained.

**d) Fourth Generation**

From the perspective of assessing patient safety, Attar et al., (2016) propose a configuration which investigates the thermal effect of superparamagnetic np on human cells, present a study considering general details on the design and construction of the configuration needed to generate a safe B to examine the thermal effect of superparamagnetic np on human cancer cells, then performed a series of experimental tests to study the effect of B on the cells for 30 minutes, which allowed them to calculate the temperature rise...
and specific absorption. While it is true, hyperthermia treatment (Eivazzadeh-Keihan et al., 2019) is a mechanism to destroy malignant cells by increasing tissue temperature up to a range of 42 - 45°C, temperatures above 45 - 56°C, can cause necrotizing damage and subsequent tissue inflammation (Shabestari Khiban, Farshbaf, Akbarzadeh, & Davaran, 2017). In this regard, ferromagnetic materials are commonly used to treat hyperthermia and the general procedure involves the allocation of magnetic particles of various sizes depending on the type of treatment to the tissue, then, when the particles generate heat through two mechanisms (including hysteresis and eddy currents), the tissue is exposed to an alternating B.

Among the advances in this fourth generation, it is important to mention the work of Al-Jamal et al., (2018), who performed in vivo experimentation based on a solid theoretical foundation for the design of a magnetic nanocarrier, capable of magnetizing uptake after intravenous administration, in order to elucidate the parameters necessary for the detection of magnetic tumors. Because long-circulating polymeric magnetic nanocarriers are capable of encapsulating increasing amounts of superparamagnetic iron oxide np (SPIONs) in a biocompatible oil carrier, they were able to study the effects of SPION loading and applied B intensity on magnetic tumor targeting in tumor-bearing mice.

Another important element is the fact that the high loading of SPIONs eliminates the need to use highly magnetized np and the oil core promotes high hydrophobic drug loading, compared to polymer-coated SPIONs. The objective of this experiment was to evaluate the key factors influencing magnetic targeting efficiency, including the loadings of SPIONs on m-NC (polymeric oil-core magnetic nanocapsules) and the magnitude of the magnetic force applied at a distance. Under controlled conditions, they quantified magnetic targeting in vivo and found that it was directly proportional to SPIONs loading and B intensity, however, higher SPIONs loading resulted in reduced blood circulation time and stabilization of magnetic targeting.

V. Diagnostic Imaging with NP

Due to the physicochemical properties presented by nanomaterials, the development of nanodevices as contrast agents in medical imaging has clear advantages over traditional agents used in the diagnosis of diseases, among which we can mention: better optical dispersion (absorption of light in the material, with a clearer visual spectrum), increased biocompatibility, decreased probability of denaturation and especially, their ability to bind to ligands, which turns them into devices with multiple functions that bind to cells, simultaneously allowing imaging for diagnosis and transport of drugs to specific sites, thus, achieving targeted and efficient treatment (Minbashi, Kordbacheh, Ghobadi, & Tuchin, 2020).

Nan, Suciu, Ardelean, Senila & Turcu (2020), report a simple reaction strategy for the synthesis of magnetic iron oxide np's stabilized with ethylenediaminetetraacetic acid (EDTA) followed by the chelation reaction of gadolinium (Gd) ions. These results show that these magnetic nanosystems represent a promising dual-mode contrast in agents for MRI applications with biomedical applications in mind.

Another type of contrast agent used for feature detection are SPIONs, due to their long half-life and small diameter, they provide a variety of possibilities to visualize intracellular targets, they can also be coupled with fluorescent dyes so that these particles can be detected in vitro and in vivo by optical fluorescence methods.

In this technique, SPIONs are inhibited by the binding of polyethylene glycol (PEG) chains that are anchored by peptide substrates shed by proteases, in diagnostic imaging, dextran-coated SPIONs provide stability for imaging, such as magnetic resonance imaging, computed tomography and optical fluorescence (Cicha, Lyer, Alexiou, & Garlichs, 2013).

In this direction, Nahrendorf et al., (2014) performed a study, where single-crystalline fluorochromelabeled SPIONs in the infrared were chelated with DTPA (diethylenetriaminepentaacetic acid) to allow binding of the PET radiotracer 64 Cu. While the iron oxide core provided the MRI contrast, the fluorochrome served for fluorescence imaging (fluorescence microscopy, flow cytometry and fluorescence mediated tomography), and the 64Cu radiotracer allowed PET (positron emission tomography) imaging, while the iron oxide core provided the MRI contrast.

The reported results show a trend towards the increasing use of SPIONs in various biomedical applications.

VI. Implementation in Colombia

Jaimez, Gonzales, Granados, Álvarez & Espitia, (2012) of the Pontificia Universidad Javeriana carried out a review article to see what advances and expectations there are in surgery to date, explaining what nanotechnology consists, its basic principles and some utilities in the field of surgery. On the other hand, Mendez and Muñoz [43] of the National University of Colombia wrote an article describing the clinical and molecular characteristics of premalignant lesions and oral cancer, as well as diagnostic methods using nanotechnology (nanochips, nanosensors, etc.) as an effective method for the early detection of cancer. Rodríguez, Moyano and Roa [44] from the Universidad Distrital Francisco Jose de Caldas, obtained a mathematical model and a computational simulation.
describing the trajectory of magnetic np injected near the target tissue. The magnetic np propagate along the blood vessel in the Z-direction and point to the target area through a cylindrical magnet located outside the body generating a constant B.

Likewise, Gallo and Ossa [45] from the University of Antioquia carried out a study where they evaluated two silver np synthesis processes, using, in addition, a biofunctionalization process with polyethylene glycol (PEG) to improve the anchoring properties and biocompatibility of the np, for possible treatments against skin cancer.

In the master’s thesis in engineering of Pantoja, (2020) of the Universidad Distrital Francisco José de Caldas, he has focused on proposing a mathematical model that can estimate the trajectory of NPM through the action of an external B and the blood flow is obtained through computational simulation. The model includes forces that significantly affect NPM dynamics, including magnetic fields generated by magnets, scattering forces, and drag. Molecular dynamics results show that NPM under the action of a B will be captured and attracted by it, so that they can be directed to the proposed target.

The reported results show that although there is no defined line of research on the use of np in Colombia, they nevertheless highlight the possibility of joining efforts to strengthen this field of knowledge.

VII. Conclusion

The np seen as drug nanocarriers play a leading role and it is in this direction in which research has been carried out, from this perspective to characterize the np and evaluate its evolution, it is identified that currently the work is focused on superparamagnetic np. The review carried out provides clarity regarding the evolution of np, as well as the importance of understanding how their kinematics are through the blood, seen as a biomagnetic fluid, a characteristic that has allowed the evaluation of strategies for directing nanoparticles that move through this medium, in this direction the main advances are associated with SPIONS for their biomedical application. There are many challenges from the treatment of diseases, starting from an accurate diagnosis to achieve an effective treatment, which involves a reduction of the adverse effects that these may have on the organism of the treated subject, in this sense the np offer a viable possibility both in diagnosis and therapy with low adverse effects, due to the possibility of targeting the treatment.

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- Diagrams
- Graphs
- Illustrations
- Lectures

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Authorship Policies

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

During submission of the manuscript, the author is confirming an exclusive license agreement with Global Journals which gives Global Journals the authority to reproduce, reuse, and republish authors’ research. We also believe in flexible copyright terms where copyright may remain with authors/employers/institutions as well. Contact your editor after acceptance to choose your copyright policy. You may follow this form for copyright transfers.

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 Electronic 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 clichês. 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.
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.

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