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Simulation of the Outlet Temperature using Meteorology of the City of El Jadida-Morocco

By Meryem El Badaoui & Abdelatif Touzani

Abstract- This article is a continuation of the previous article "Modeling of a parabolic trough using two heat transfer fluids and an economic estimation in the Moroccan dairy industry," presenting new parameters and results. Its objective is to simulate the temperature of the chosen fluid, which is water by using the meteorology of the city of El Jadida, city of the dairy industry.

We presented the energy balance of the parabolic trough then the thermophysical properties of the water, as well as the meteorology of El Jadida by taking the maximum, minimum temperature of the year plus the range of the wind speed influenced the glass cover of the absorber. We finished with a visualization of water velocity within the absorber.

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Abstract - This article is a continuation of the previous article" Modeling of a parabolic trough using two heat transfer fluids and an economic estimation in the Moroccan dairy industry," presenting new parameters and results. Its objective is to simulate the temperature of the chosen fluid, which is water by using the meteorology of the city of El Jadida, city of the dairy industry.

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I. INTRODUCTION

According to the recent article "Modeling of a parabolic trough using two heat transfer fluids and an economic estimation in the Moroccan dairy industry"[1], We made a comparison between two heat transfer fluids based on several parameters including the heat exchange coefficient, the Grashof number as well as their environmental and economic impact.

This comparison made it possible to choose water as the heat transfer fluid within the industry. It is in this context, and based on the metrology of the city of El Jadida-Morocco, the simulation proposed below was established under Comsol in transient mode using water as heat transfer fluid.

II. THERMAL BALANCE OF PARABOLIC TROUGH

Acording to the previous article, we focused on the description of the parabolic trough as well as we presented its thermal balance. Below we will briefly introduce it. [2][3]

Figure 1: Description of absorber pipe

Figure 2: Temperatures inside the pipe

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e-mails: meryemelbadaoui@research.emi.ac.ma, atouzanikia@gmail.com
b) Thermal balance

The characteristic equation using water

\[ \rho_j C_p \pi D_{ai} \frac{\partial T_f(x,t)}{\partial t} = \rho_j C_p D_j \frac{\partial T_f(x,t)}{\partial x} + q_u(x,t) \]

\[ q_u(x,t) = h_a \pi D_{ai}(T_a(x,t) - T_f(x,t)) \]

\[ T_{fi} = \frac{1}{1 + \frac{\Delta t D_f}{\Delta x \pi D_{ai}}} \left[ T_{fi(-1)} \left( 1 + \frac{\Delta t \rho_f C_p l D_j}{\rho_f C_p l D_{ai} \pi \Delta x} \right) + \frac{\Delta t}{\rho_f C_p l D_{ai} \pi \Delta x} q_u(T_{ai}, T_{fi}) \right] \]

Using the constants for simplifications, we have the equations below:

\[ A = [1 - \frac{D_j \Delta t}{\Delta x \pi D_{ai}}] \quad \frac{T_{fi}^{t+1}}{} = AT_{fi}^t + B_{j(i-1)} + C \]

\[ B = \frac{\rho_f l D_j}{\rho_f C_p l D_{ai} \pi \Delta x} \quad C = \frac{q_u}{\rho_f C_p l D_{ai} \pi} \]

The characteristic equation of the glass cover

\[ \frac{\partial T_a(t)}{\partial t} = \frac{1}{\rho_a C_{pa} A} \left[ q_{ab}(t) - q_{a,v}(t) - q_u(t) \right] \]

\[ q_{ab} = \rho_{sel} \alpha_{ab} \tau_v S_G q_{a,v} = \frac{2\pi K_{airff}}{\ln \left( \frac{D_{ai}}{D_{ae}} \right)} (T_a - T_v) + \frac{\sigma \pi D_{ae} (T_a^2 - T_v^2)}{1 - \varepsilon_v} + \frac{1 - \varepsilon_v}{\varepsilon_v} \left( \frac{D_{ae}}{D_{ai}} \right) \]

\[ T_{a}^{t+1} = T_a^t + \frac{\Delta t}{\rho_a C_{pa} A} \left[ q_{ab}(t) - q_{a,v}(t) - q_u(t) \right] \]

\[ T_{a}^{t+1} = T_a^t + D \quad \text{with:} \quad D = \frac{\Delta t}{\rho_a C_{pa} A} \left[ q_{ab}(t) - q_{a,v}(t) - q_u(t) \right] \]

Water thermophysical properties

\[ \frac{\partial T_v(t)}{\partial t} = \frac{1}{\rho_v C_{pv} A_v} \left[ q_{a,v}(t) - q_{v,amb}(t) \right] \]

\[ q_{v,amb}(t) = h_{v,amb} S_v (T_v - T_{amb}) + \varepsilon_v \sigma S_v (T_v^4 - T_{amb}^4) \]

\[ T_v^{t+1} = T_v^t + \frac{\Delta t}{\rho_v C_{pv} A_v} \left[ q_{a,v}(t) - q_{v,amb}(t) \right] \]

\[ T_v^{t+1} = T_v^t + E \quad \text{with:} \quad E = \frac{\Delta t}{\rho_v C_{pv} A_v} \left[ q_{a,v}(t) - q_{v,amb}(t) \right] \]

Since we chose to work with water as heat transfer fluid, this implies to present its thermophysical properties below.

**Volumic mass (Kg/m^3):**

\[ -0.0032T^2 - 1.6126T + 799.26; \]

**Heat capacity (J/Kg.K):**

\[ (276370 - 2090.1T + 8.125T^2 - 0.0141167T^3 + 9.3701.10^{-6}T^4)/18.051 \]

**Thermal conductivity (W/m.K):**

\[ -0.432 + 0.00572557 - 8.078.10^{-6}T^2 + 1.86.10^{-9}T^3 + 1.861.10^{-9} \]

**Dynamic viscosity (Pa.s):**

\[ \exp(-52.843 + \frac{3703.6}{T} + 5.866 \ln(T) - 5.87910^{-20}T^{10}) \]
III. DNI OF EL JADIDA DURING THE YEAR

According to Solar Atlas Masen [4][5], we were able to generate the following results:

**Figure 3: DNI of EL Jadida from March to September**

<table>
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<tr>
<th>Month</th>
<th>March</th>
<th>April</th>
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<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
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<tr>
<td>DNI (Kwh/m²)</td>
<td>151</td>
<td>172</td>
<td>183</td>
<td>171</td>
<td>158</td>
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<td>156</td>
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**Figure 4: DNI of EL Jadida from October to February**

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<tr>
<th>Month</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
<th>February</th>
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<tr>
<td>DNI (Kwh/m²)</td>
<td>130</td>
<td>117</td>
<td>116</td>
<td>120</td>
<td>122</td>
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IV. METEOROLOGY OF EL JADIDA-MOROCCO

In this paragraph, we will look at the meteorology of El Jadida during the year 2019 by presenting the maximum and minimum temperatures and the wind speed.[6][7]

a) Temperatures of EL Jadida in 2019

According to the Accu Weather website [8], we were able to take the meteorological history of the city in 2019 to identify the maximum and minimum temperatures of the year to use them in our simulation.
Figure 5: Maximum and minimum average temperature for the year 2019

The figure above shows, on the one hand, the daily average maximum and minimum temperatures of the year. On the other hand, the months with high and low temperatures are September at 26°C and January with 8°C.

Figure 6: Average Maximum temperature in 2019
The figures beyond show the number of days per month, reaching peak temperatures for the first diagram, while the second presents the days with the lowest temperatures.

Figures 8 and 9 present the months having the maximum and minimum temperature of the year, recording on January 6, the lowest temperature of the year: 2 °C as for September 30 marks the highest temperature of the year: 32 °C.
b) Wind speed during 2019

The figures above show the evolution of wind speed in 2019, varying from 8km/h to 73Km/h. We notice in the second diagram a variation of the wind speed compared to the days of each month of the year.
V. Results and Discussions

**Figure 12: Ambient temperature on 6 January (1) and on 30 September (2)**

The figure above shows us the variation of the ambient temperature during the day, starting from 7h to 19h. We observe on 6 January (1), marked the minimal temperature of the year, reaching a maximum of 293K at 10 a.m.

On the one hand and on the other hand, we notice that a higher temperature: 304K at 1p.m was noticeable on 30 September.

Outlet water temperature on January 6 and September 30

**Figure 13: Outlet water temperature on January 6 (1) and September 30 (2) using Comsol Multiphysics**
Figure 13 shows the simulation under Comsol Multiphysics of the water temperature at the outlet on January 6 and September 30. Take an outlet temperature exceeding 290K for January 6, while September 30 marks a temperature exceeding 400K.

For figure 14 of the convergence curve of the simulation converges quickly. This convergence shows us the validity of our simulation.

The figure 15 presents the temperature evolution from 7h to 19h of the two days mentioned above.
Variation of Glass cover temperature depending on wind speed

In figure 16, we notice a decreasing effect of the wind speed on the glass cover temperature for the three ambient temperatures.

Water speed in the parabolic trough

This figure allowed us to visualize the interior of the parabolic by presenting the speed of the water in the absorber by reaching a speed of 0.13m/s at the parabolic through the outlet.
Variation of temperatures depending on solar irradiation

Fig. 18: Temperature variation according to solar irradiation during January 6

Fig. 19: Temperature variation according to solar irradiation during September 30

The figures above show the variations of the three temperatures during January 6 and September 30 depending on solar irradiation.

It can be seen that solar irradiation has an effect on the three temperatures, more precisely the absorber temperature, its increase implies an increase in temperatures, recording increases in the temperatures of the fluid, the absorber and the glass respectively: 470K, 474K and 327K for a maximum irradiation of 500w / m² during January 6, more on September 30 and for a maximum irradiation of 750w / m² at temperatures of 577K, 581K and 346K.

VI. Conclusion

This labor made it possible to work with the water chosen at the end of the previous work by simulating its temperature at the outlet.

This study, first of all, made it possible to visualize the meteorology of the city by identifying January 6 as the day with minimum temperature and September 30 having a maximum temperature, as well as the variation of the temperature at the exit during these two days.

Also, we exposed the variant wind speed from 8km / h to 73Km / h in 2019, as well as its influence on the glass cover temperature.

Acknowledgment

This work was done in the laboratory “Applied Thermodynamics and Solid Combustibles (ATSC)”, Mohammed School of Engineers (EMI), Rabat-Morocco, under the direction of professor Doctor Abdellatif TOUZANI.

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1. EL BADAOUI MERYEM and TOUZANI ABDELATIF, 2020, Modeling of a parabolic trough using two heat transfer fluids and an economic estimation in the Moroccan dairy industry.
Results of Comparative Experimental Studies to Identify the Effectiveness of the New Design of the End Grinding Wheel

By Hassan Ahmad Husseynov & Chingiz Mirza Mammadov
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Abstract- The article presents the results of comparative experimental studies to identify the effectiveness of the new design of the end grinding wheel. The analysis of the obtained empirical models shows that the roughness of surfaces ground with a new design wheel is much lower than that of a standard grinding wheel. This is due to the fact that the creation of discontinuity on the frontal zone of the working end with the profiling of the protrusions along the Archimedean spiral eliminates periodic impacts, increases the number of cutting grains, creates conditions for a relatively uniform distribution of the allowance between them and increases the meticulous capacity of the continuous part of the working end of the wheel.

Keywords: grinding wheel, roughness, surface quality, empirical model, archimedean spiral, efficiency, cutting conditions.

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Results of Comparative Experimental Studies to Identify the Effectiveness of the New Design of the End Grinding Wheel

Сравнительные экспериментальные исследования шероховатости поверхности при торцовом шлифовании кругом новой конструкции и стандартным кругом

Hassan Ahmad Husseynov & Chingiz Mirza Mammadov

Abstract - The article presents the results of comparative experimental studies to identify the effectiveness of the new design of the end grinding wheel. The analysis of the obtained empirical models shows that the roughness of surfaces ground with a new design wheel is much lower than that of a standard grinding wheel. This is due to the fact that the creation of discontinuity on the frontal zone of the working end with the profiling of the protrusions along the Archimedean spiral eliminates periodic impacts, increases the number of cutting grains, creates conditions for a relatively uniform distribution of the allowance between them and increases the meticulous capacity of the continuous part of the working end of the wheel.

Keywords: grinding wheel, roughness, surface quality, empirical model, archimedean spiral, efficiency, cutting conditions.

Реферат - В статье изложены результаты сравнительных экспериментальных исследований по выявлению эффективности новой конструкции торцового шлифовального круга. Анализ полученных эмпирических моделей показывает, что шероховатость поверхностей, шлифованных кругом новой конструкции значительно ниже, чем шлифованных стандартным кругом. Это объясняется тем, что созданием прерывистости на фронтальной зоне рабочего торца с профилированием выступов по архимедовой спирали устраняются периодические удары, увеличиваясь число режущих зерен, создаются условия для относительно равномерного распределения припуска между ними и повышается выжилающую способность сплошной части рабочего торца круга.

Ключевые слова: шлифовальный круг, шероховатость, качество поверхности, эмпирический модель, архимедова спираль, эффективность, режимы резания.

I. ВВЕДЕНИЕ

Масштабы применения шлифовальных операций, появление новых машиностроительных материалов и новых алмазно-абразивных инструментов для их обработки вызывает необходимость в более детальном изучении физической сущности этого процесса. Анализ процесса шлифования неуклонно приводит к мысли, что при этом значительная часть механической работы тратится на трение и соответственно приводит к повышенному тепловому воздействию на обрабатываемую поверхность, а в последствии к ухудшению геометрических параметров шлифованных поверхностей и снижению физико-механических свойств поверхностного слоя обрабатываемой детали.

В качестве примера проведем анализ процесса торцевого шлифования, отличающейся с наибольшей площадью контакта. Идея снижения теплового воздействия на обрабатываемую поверхность посредством усовершенствования шлифовального инструмента, в частности торцевого шлифовального круга, привела к появлению кругов с прерывистыми, экцентричными, наклонными и др. поверхностями. Этими кругами хотя и удается снижение теплового воздействия на обрабатываемую поверхность, однако, они неуклонно ведут к повышению вибрации в технологической системе из-за ударного воздействия при прерывистом шлифовании и неуравновешенности, при шлифовании с экцентричными и наклонными кругами. Ударное воздействие и неуравновешенность шлифовальных кругов, в свою очередь, приводит к ухудшению качества шлифованных поверхностей, повышенному износу круга, преждевременному выходу из строя шлифовального и других узлов станка.

II. ПОСТАНОВКА ЗАДАЧИ

Анализируя работу кругов с прерывистой рабочей поверхностью нетрудно убедиться в том, что работа резания при этом производится в основном зернами, расположенными на фронтальной части
рабочего выступа с высотой величины продольной подачи детали на оборот круга. Этому свидетельствует интенсивное выкрашивание зерен этой зоны из связи[1]. По мере износа происходит само оформление внешнего профиля выступа, образуя некоторый угол атаки к плоскости резания. Указанное явление особенно характерно при глубинном и черновом многопроходном шлифовании.

При этом основным очагом тепловыделения в контактной зоне является фронтальная -режущая полоса, в последующих, фактически работающие зерна попадая в уже прорезанные цараны производят работу выхаживания. Причем выхаживающие способности условных полос возрастают по мере удаления от фронтальной зоны по убывающей геометрической прогрессии. Таким образом, рабочий торец выступа условно разбивается на две части – первая режущая фронтальная полоса, вторая – последующие выхаживающие полосы.

Следовательно, снижение интенсивности тепловыделения в режущей фронтальной части рабочего торца круга, где она имеет доминирующее значение, путем создания прерывистости в этой зоне и устранения очагов возникновения вибраций выполнением выхаживающую часть сплошным, являются наиболее оптимальными решениями повышения эффективности процесса торцового шлифования.

**Рис. 1:** Торцовой шлифовальный круг выступами, очерченными по архимедовой спирали

### III. КОНСТРУКТИВНОЕ РЕШЕНИЕ

Для устранения периодических ударов в прерывистой зоне и тем самым источников вибраций, требуется профилирования режущих выступов прерывистой части рабочего торца шлифовального круга, а также и тем самым источников вибраций, чтобы способствовало увеличению количества режущих зерен рабочего выступа и созданию условий для относительно равномерного распределения между ними припуска, приходящего на один выступ прерывистой части фронтальной полосы. Данная проблема решается очертанием профиля режущего выступа по архимедовой спирали, т.е. переход от впадин к выступу в режущей фронтальной полосе выполняется по архимедовой спирали, посредством суммирования двух равномерных движений – поступательного в результате продольной подачи детали и вращательного посредством вращательного движения шлифовального круга. Для реализации вышеперечисленных суждений разработана новая конструкция торцового шлифовального круга, которая была защищена в Государственном комитете по стандартизации метрологии и патентам и получен одноименный патент под № 0183 (Рис. 1).

### IV. МЕТОДИКА

Для определения эффективности новой конструкции торцового шлифовального и рациональных условий ее применения были проведены экспериментальные исследования по ортогональному планированию второго порядка. Входные переменные экспериментов были выбраны исходя из степени их воздействия на исследуемый процесс. Рассматривались все существенные факторы процесса торцового шлифования. Осевая, первоначально выбранных факторов был произведен на основе анализа априорной информации и теоретических исследований автора[5]. При отсеве также внимание на возможности количественной оценки выбранных факторов, их управляемости, исходя из технических возможностей станка, точки измерения, назначения необходимого уровня в соответствии со строками матрицы планирования и его поддержки во время опыта. С учетом всех этих требований в качестве входных параметров процесса шлифования были выбраны: скорость круга , скорость детали и подачи на глубину , комбинации которых наиболее воздействуют на шероховатость шлифованной поверхности.

Все входные переменные эксперимента являются независимыми и управляемыми. Связанность этих факторов совместима и представляет режим шлифования, а их комбинации, в соответствии со
строками матрицы планирования, исходя из технических и технологических возможностей операции торцового шлифования, осуществимы.

В качестве выходных переменных экспериментальных исследований выбраны параметры шероховатости шлифованной поверхности. Теоретические исследования, проведенные в работах [1-3], позволили определить параметры новой конструкции шлифовального круга, в том числе характеристику архимедовой спирали и оптимальное количество выступов прерывистой зоны. Исходя из степени влияния факторов на величину выходных параметров процесса шлифования и величину ошибки их измерения были определены интервалы варьирования факторов и (Табл.1).

Таблица 1: Уровни факторов и интервалы варьирования

<table>
<thead>
<tr>
<th>Уровни факторов</th>
<th>Обозначение</th>
<th>( V_{V_0} ) (п в об/мин)</th>
<th>( V_{V_t} ) м/мин</th>
<th>( t ) мм</th>
</tr>
</thead>
<tbody>
<tr>
<td>Основной уровень</td>
<td>0</td>
<td>15,7(3000)</td>
<td>3</td>
<td>0,03</td>
</tr>
<tr>
<td>Интервал варьирования</td>
<td>( \vec{X}_i )</td>
<td>1,05</td>
<td>1,5</td>
<td>0,015</td>
</tr>
<tr>
<td>Верхний</td>
<td>+1</td>
<td>16,75(3200)</td>
<td>4,5</td>
<td>0,045</td>
</tr>
<tr>
<td>Нижний</td>
<td>-1</td>
<td>14,65(2800)</td>
<td>1,5</td>
<td>0,015</td>
</tr>
<tr>
<td>Звёздные Верхний</td>
<td>+1,215</td>
<td>16,97575(3536)</td>
<td>4,8225</td>
<td>0,048225</td>
</tr>
<tr>
<td>Нижний</td>
<td>-1,215</td>
<td>14,42425(2464)</td>
<td>1,1775</td>
<td>0,011775</td>
</tr>
</tbody>
</table>

Экспериментальные исследования были проведены на универсально-заточном станке мод.3А64Д, оборудованном гидравлической продольной подачей. Для сравнительной оценки выходных параметров проведенных опытов, эксперименты были проведены с применением стандартного чашечного круга типа ЧК 100х25х20 с характеристикой 14A40CM1K с сплошной рабочей поверхностью и новой конструкцией торцового шлифовального круга с прерывистой режущей частью рабочей поверхности. При этом обеспечивая идентичность всех условий эксперимента, менялся только шлифовальный круг. Опытные образцы заготовок были приняты из стали 40Х с твердостью 40 НRС с размерами поперечного сечения 30х20.

Измерение геометрических параметров производилось с использованием нижеперечисленных методов и средств измерений:

1. Шероховатость – среднегеометрическое отклонение профиля \( R_a \) профилометром- профилографом мод. 130 завода «Калибр» г. Москва;

2. Волноликость – высота волн \( W_{BY} \) по волнограммам, снятых на профилограф – профилометре 130 с применением приспособления для измерения волноликости;


V. Эксперименты

Опыты были поставлены по составленной матрице планирования (Табл.2) обладающей оптимальными свойствами. На основе априорных данных о характере искомой зависимости установлено, что [1-3] для определения зависимости шероховатости поверхности от скорости круга, скорость детали и подачи на глубину, описания поверхности отклика полиномом первого порядка недостаточно, поэтому для получения адекватной аппроксимации исследуемого процесса воспользовались полиномом второго порядка. Математическая модель второго порядка представляется в виде [4]

\[
M \{Y\} = \eta = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i>j}^{k} \beta_{ij} X_i X_j + \sum_{i=1}^{k} \beta_{ii} X_i^2
\]

(1)

\( \beta_0 \)– свободный член

\( \beta_i \)– коэффициенты при линейных членах
$\beta_i$ - коэффициенты при взаимодействии факторов. Кодирование значения факторов произведено с помощью формулы преобразования [4]

$$X_i = \frac{\tilde{X}_i - \tilde{X}_0}{\Delta \tilde{X}_i} \quad (2)$$

Табл. 2: Ортогональный план второго порядка для $k=3$

<table>
<thead>
<tr>
<th>V</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>R(_{as})</th>
<th>R(_{an})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14,65</td>
<td>1,5</td>
<td>0,015</td>
<td>0,49</td>
<td>0,4</td>
</tr>
<tr>
<td>2</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>16,75</td>
<td>1,5</td>
<td>0,015</td>
<td>0,29</td>
<td>0,2</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>14,65</td>
<td>4,5</td>
<td>0,015</td>
<td>0,55</td>
<td>0,4</td>
</tr>
<tr>
<td>4</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>16,75</td>
<td>4,5</td>
<td>0,015</td>
<td>0,41</td>
<td>0,3</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>14,65</td>
<td>1,5</td>
<td>0,045</td>
<td>0,64</td>
<td>0,52</td>
</tr>
<tr>
<td>6</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>16,75</td>
<td>1,5</td>
<td>0,045</td>
<td>0,44</td>
<td>0,35</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>14,65</td>
<td>4,5</td>
<td>0,045</td>
<td>0,7</td>
<td>0,6</td>
</tr>
<tr>
<td>8</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>16,75</td>
<td>4,5</td>
<td>0,045</td>
<td>0,56</td>
<td>0,46</td>
</tr>
<tr>
<td>9</td>
<td>-1,215</td>
<td>0</td>
<td>0</td>
<td>14,424</td>
<td>3</td>
<td>0,03</td>
<td>0,6</td>
<td>0,51</td>
</tr>
<tr>
<td>10</td>
<td>+1,215</td>
<td>0</td>
<td>0</td>
<td>16,976</td>
<td>3</td>
<td>0,03</td>
<td>0,4</td>
<td>0,38</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>-1,215</td>
<td>0</td>
<td>15,7</td>
<td>1,1775</td>
<td>0,03</td>
<td>0,35</td>
<td>0,24</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
<td>+1,215</td>
<td>0</td>
<td>15,7</td>
<td>4,8225</td>
<td>0,03</td>
<td>0,65</td>
<td>0,55</td>
</tr>
<tr>
<td>13</td>
<td>0</td>
<td>0</td>
<td>-1,215</td>
<td>15,7</td>
<td>3</td>
<td>0,012</td>
<td>0,43</td>
<td>0,31</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>0</td>
<td>+1,215</td>
<td>15,7</td>
<td>3</td>
<td>0,048</td>
<td>0,57</td>
<td>0,45</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15,7</td>
<td>3</td>
<td>0,03</td>
<td>0,5</td>
<td>0,4</td>
</tr>
</tbody>
</table>

Оценка коэффициентов регрессии производятся по формулам [4] с учетом численных значений моментов и вспомогательных коэффициентов

$$b_0 = \frac{\sum_{u=1}^{n} r_u \bar{Y}_u}{N}; \quad (3)$$

$$b_u = \frac{\sum_{v=1}^{n} r_v X_{i_v} Y_u}{\sum_{g=1}^{N} (X_{i_g}^4 - X_{i_g}^2 X_{i_g}^2)}; \quad \begin{cases} b_0 & \text{при } i = 0 \\ b_i & \text{при } i \neq 0 \end{cases}$$

$$b_{uv} = \frac{\sum_{v=1}^{n} r_v X_{i_v} \bar{Y}_u}{\sum_{g=1}^{N} X_{i_g}^2}; \quad \begin{cases} b_{00} & \text{при } i = 0 \\ b_{0i} & \text{при } i \neq 0 \end{cases}$$

$$b_{vu} = \frac{\sum_{v=1}^{n} r_v X_{j_v} \bar{Y}_u}{\sum_{g=1}^{N} X_{i_g}^2 X_{j_g}^2}; \quad \begin{cases} b_{00} & \text{при } j = 0 \\ b_{0j} & \text{при } j \neq 0 \end{cases}$$
Оценка коэффициента $b_0$, входящего в исходную модель производится по формуле [4]

$$b_0 = b_0^1 - \lambda_2 \sum_{i=1}^{k} b_i$$

где $\lambda_2$ - момент второго порядка.

$$\lambda_2 = \frac{\sum_{g=1}^{N} X_{i,g}^2}{N}; \quad i = 1,2,...k$$

где $N$ - общее число опытов; $r_v$ - число повторных опытов в $r$-й точке плана;

$n$ - число разных точек в плане; $r$-порядковый номер точки плана;

$\bar{Y}_v$ - средний отклик по $r$ опытом в точке с номером $r$; $k$ - число факторов;

$\hat{Y}$ -оценка математического ожидания отклика

$X_i$ - переменной факторы; $Y_u$ - параметр оптимизации, подлежащий изучению;

$i$ - номер повторения испытания; $j$ - номер уровня фактора.

Построчные дисперсии подсчитываются по формуле [4]

$$S_v^2 = \frac{\sum_{j=1}^{r} (Y_{ij} - \bar{Y}_v)^2}{r - 1}$$

объединенная дисперсия параметра оптимизации по формуле [4]

$$S^2 \{Y\} = \frac{\sum_{j=1}^{r} (Y_{ij} - \bar{Y}_u)^2}{r - 1}.$$  

Дисперсия коэффициента регрессии $S^2 \{b_i\}$ при равномерном дублировании опытов по точкам с числом повторных опытов $r$ определяется по формуле [4]

$$S^2 \{b_i\} = \frac{S^2 \{Y\}}{nr}.$$  

Дисперсия адекватности $S^2_{ag}$ определяется по формуле [4]

$$S^2_{ag} = \frac{SS_{ag}}{f_{ag}} = \frac{\sum_{v=1}^{y} (\bar{Y}_v - \hat{Y}_v)^2}{n - m}.$$  

где $m$ - число коэффициентов в модели; $SS_{ag}$ -сумма квадратов отклонений
\( f_{ag} \) - число степеней свободы для дисперсии неадекватности.
Расчет коэффициентов уравнения произведем по формулам (3)
Для стандартного круга

\[
b'_0 = \frac{\sum_{v=1}^{15} \bar{Y}_v}{15} = 0,5053
\]

\[
b_i = \frac{1}{10,954} \sum_{v=1}^{15} X_i \bar{Y}_v \; ; \; b_1 = -0,084 \; b_2 = 0,066 \; \; b_3 = 0,07
\]

\[
b_j = \frac{1}{8} \sum_{v=1}^{15} X_i X_j \bar{Y}_v \; ; \; b_{12} = 0,015 \; b_{13} = 0 \; \; b_{23} = 0
\]

\[
b_{ii} = 3,45 \times \frac{1}{45} \sum_{v=1}^{15} X_i^2 \bar{Y}_v \; ; \; b_{i}^2 = 0,0748 \; \; b_{i}^2 = 0,062 \; \; b_{i}^2 = 0,062
\]

Для круга новой конструкции

\[
b'_0 = \frac{\sum_{v=1}^{15} \bar{Y}_v}{15} = 0,4
\]

\[
b_i = \frac{1}{10,954} \sum_{v=1}^{15} X_i \bar{Y}_v \; ; \; b_i = -0,07 \; b_2 = 0,06 \; \; b_3 = 0,073
\]

\[
b_j = \frac{1}{8} \sum_{v=1}^{15} X_i X_j \bar{Y}_v \; ; \; b_{12} = 0,016 \; b_{13} = -0,00125 \; \; b_{23} = 0,01125
\]

\[
b_{ii} = 3,45 \times \frac{1}{45} \sum_{v=1}^{15} X_i^2 \bar{Y}_v \; ; \; b_{i}^2 = -0,062 \; \; b_{i}^2 = 0,058 \; \; b_{i}^2 = 0,065
\]

Табл. 2

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<th>X2</th>
<th>X3</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>R_{ae}</th>
<th>R_{an}</th>
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<td>3</td>
<td>0,03</td>
<td>0,5</td>
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</tr>
</tbody>
</table>
Оценку коэффициента $b_0$, входящего в исходную модель, находим по формуле (4) [4]

$$b_0 = b_0' - 0,7303(b_1^2 + b_2^2 + b_3^2)$$

Для стандартного круга $b_0 = 0,456$

для круга новой конструкции $b_0 = 0,355$.

Уравнение регрессии в кодированных переменных будет:

для стандартного круга

$$\hat{Y} = 0,456 - 0,081X_1 + 0,066X_2 + 0,071X_3 + 0,015X_1X_2 - 0,0748X_1^2 + 0,062X_2^2 + 0,06X_3^2,$$  \(9\)

для круга новой конструкции

$$Y = 0,355 - 0,070X_1 + 0,06X_2 + 0,073X_3 + 0,016X_1X_2 + 0,00125X_1X_3 + 0,01125X_2X_3 - 0,062X_1^2 + 0,058X_2^2 + 0,065X_3^2.$$  \(10\)

Для проверки достоверности полученных моделей была проведена проверка ряд гипотез: об однородности дисперсий, значимости коэффициентов регрессии и об адекватности модели.

Построенные дисперсии подсчитываем по формуле (5)

$$S^2_v = \sum_{j=1}^r \frac{(Y_{ij} - \bar{Y}_v)^2}{r - 1},$$

Дисперсию параметра оптимизации $S^2(Y)$ подсчитаем на основе данных таблицы по формуле (6): для стандартного круга

$$S^2\{Y\} = \frac{\sum_{v=1}^n S^2_v}{\frac{n}{15}} = \frac{0,365}{15} = 0,02434,$$

для круга новой конструкции

$$S^2\{Y\} = \frac{\sum_{v=1}^n S^2_v}{\frac{n}{15}} = \frac{0,3801}{15} = 0,02534,$$

где $S^2_v$ – дисперсия отклика по результатам в v-й точке плана, где производится rv повторных опытов.

Проверку значимости каждого коэффициента проводим по t-критерию Стьюдента. При равномерном дублировании опытов по точкам с числом повторных опытов r дисперсия коэффициента регрессии $S^2(b_i)$ определяется по формуле для стандартного круга

$$S^2\{b_i\} = \frac{0,2434}{nr} = \frac{0,2343}{15 \cdot 3} = 0,0005,$$

$$S\{b_i\} = 0,023$$

для круга новой конструкции.
Определим значение критерия по формуле

\[ t_i = \frac{|b_i|}{s\{b_i\}} \]

для стандартного круга

\[
\begin{align*}
t_0 &= 0,456/0,023 = 19,8; \quad t_1 = 0,085/0,023 = 3,69; \quad t_2 = 0,066/0,023 = 2,87; \\
t_3 &= 0,07/0,023 = 3,04; \quad t_{12} = 0,015/0,023 = 0,652; \quad t_{11} = 0,0748/0,023 = 3,25; \\
t_{22} &= 0,062/0,023 = 2,69; \quad t_{33} = 0,0620/0,023 = 2,69
\end{align*}
\]

для круга новой конструкции

\[
\begin{align*}
t_{0} &= 0,355/0,0237 = 15; \quad t_1 = 0,07/0,0237 = 3; \quad t_2 = 0,06/0,0237 = 2,5; \\
t_3 &= 0,073/0,0237 = 3 \\
t_{12} &= 0,016/0,0237 = 0,675; \quad t_{13} = 0,01125/0,0237 = 0,05; \quad t_{23} = 0,01125/0,47 \\
t_{11} &= 0,062/0,0237 = 2,6; \quad t_{22} = 0,058/0,0237 = 2,44; \quad t_{33} = 0,065/0,0237 = 2,74
\end{align*}
\]

Критическое значение \( t_{kp} \) находится по таблице работы [4] при \( n(r-1)=30 \) степенях свободы и заданном уровне значимости \( \alpha=5\% \): \( t_{kp}=1,697 \). Если \( t_t > t_{kp} \), гипотеза отвергается, и коэффициент \( b_i \) признаются значимым.

Построим доверительный интервал длиной \( \Delta b_i \):

для стандартного круга

\[ \Delta b_i = t_{kp} S\{b_i\} = 1,697 \cdot 5,1 = 8,8 \]

dля круга новой конструкции

\[ \Delta b_i = t_{kp} S\{b_i\} = 1,697 \cdot 0,0237 = 0,04 \]

Коэффициент значим если его абсолютная величина больше половины длины доверительного интервала. В модели стандартного круга коэффициенты, \( b_{23}, b_{33} \), в модели круга новой конструкции коэффициенты \( b_{12}, b_{23}, b_{33} \) являются незначимыми.

Таким образом, математическая модель зависимости шероховатости шлифованной поверхности от элементов режима шлифования в виде уравнения связи выходного параметра \( Y \) и переменных \( X_i \), включающего только значимые коэффициенты получается:

для стандартного круга

\[
\hat{Y} = 0,456 - 0,085X_1 + 0,066X_2 + 0,071X_3 + 0,015X_1X_2 - 0,0748X_1^2 + 0,062X_2^2 + 0,06X_3^2,
\] (9)

для круга новой конструкции

\[
Y = 0,355 - 0,07X_1 + 0,06X_2 + 0,073X_3 - 0,062X_1X_2 + 0,058X_1^2 + 0,065X_2^2 + 0,065X_3^2.
\] (10)

Для получения уравнения в в натуральных значениях элементов режима шлифования вместо \( x_i \), поставим их значения из формул преобразования [4]

\[
X_3 = \frac{V_k - 15,7}{1,05}; \quad X_2 = \frac{V_d - 3}{1,15}; \quad X_3 = \frac{t - 0,03}{0,015}.
\]
Таким образом, получим математическую модель зависимости шероховатости от параметров режима шлифования: скорости круга $V_k$, скорости детали $V_d$ и глубины резания $t$ в натуральных значениях для стандартного круга

$$Y^* = -14,337 + 2,025V_e - 0,281V_d - 11,799 t + 0,01V_kV_d - 0,068V_k^2 + 0,028V_d^2 + 275,556t^2$$ (11)

для круга новой конструкции

$$Y = -11,69 + 1,6634V_e - 0,288V_d - 12,721 t - 0,056V_k^2 + 0,026V_d^2 + 288,889 t^2$$ (12)

Статистические данные обработки результатов для стандартного круга и круга новой конструкции были приведены соответственно в таблицах 3 и 4.

### Табл. 3

<table>
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<th>Точки плана $v$</th>
<th>$Y_1$</th>
<th>$Y_2$</th>
<th>$Y_3$</th>
<th>$\bar{Y}_v$</th>
<th>$S^2_v$</th>
<th>$\hat{Y}_v$</th>
<th>$\left(\bar{Y}_v^2 - \hat{Y}_v^2\right)$</th>
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### Табл. 4

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<td>15</td>
<td>0,6</td>
<td>0,3</td>
<td>0,3</td>
<td>0,4</td>
<td>0,03</td>
<td>0,2</td>
<td>0,04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6,07</td>
<td>0,3801</td>
<td>5,56</td>
<td>0,1662</td>
</tr>
</tbody>
</table>
Проверим полученную модель на адекватность по формуле (8):
для стандартного круга

$$\sum \bar{Y}_{v} = 7,58; \quad \sum \hat{Y}_{v} = 7,587$$

$$S^2 \{Y\} = \frac{\sum_{i=1}^{n} S^2_{v}}{n} = \frac{0,365}{15} = 0,02434,$$

$$S^2_{ad} = \frac{r}{(n-m)} \sum_{i=1}^{n} [\bar{Y}_{v} - \hat{Y}_{v}]^2 = 0,038$$

$$F = \frac{S^2_{ad}}{S^2 \{Y\}} = \frac{0,038}{0,02434} = 1,56$$

для круга новой конструкции

$$\sum \bar{Y} = 6,07; \quad \sum \hat{Y} = 5,56$$

$$S^2_{ad} = \frac{r}{(n-m)} [\bar{Y}_{v} - \hat{Y}_{v}]^2 = 0,038$$

$$F = \frac{S^2_{ad}}{S^2 \{Y\}} = \frac{0,038}{0,02534} = 1,499$$

где $m$ - число членов аппроксимирующего полинома (включая свободный член),

Табличное значение критерия Фишера для числа

степеней свободы $f_{ad} = 15 - 10 = 5$, общему числу степеней свободы для объединенной дисперсии $S^2 \{Y\}$,

$f_e = 45 - 15 = 30$ и уровня значимости $\alpha = 10\%$

равно $F_{kp} = 1,6$ поскольку для рассмотренных обоих вариантов $F < F_{kp}$, полученные модели шероховатости при шлифовании стандартным чашечным кругом и кругом новой конструкции являются адекватными реальным процессам.

ВИ. ГРАФИЧЕСКАЯ ИНТЕРПРЕТАЦИЯ

На основе математических моделей (11) и (12) были построены графические зависимости

шероховатости поверхности от элементов режима резания при шлифовании со стандартным кругом и
кругом новой конструкции (рис.2, а,б,в).
Рис. 2: Графики зависимостей шероховатости от скорости резания $V_k$ (a), глубины резания $t$ (b) и скорости стола $V_d$ (c) при шлифовании со стандартным кругами и кругом новой конструкции.
VII. ЗАКЛЮЧЕНИЕ

Полученные модели (11) и (12) позволяют определить эффективность новой конструкции торцевого шлифовального круга с прерывистостью во фронтальной зоне рабочего торца и переходом от впадины к выступу по архимедовой спирали по сравнению со стандартным чашечным кругом. На основе анализа модели (12) можно определить рациональное сочетание элементов режима резания для торцевого шлифовального круга новой конструкции. Анализ графических зависимостей (рис.2а, 2б, 2в) показывает, что шероховатость поверхностей, шлифованных торцевым шлифовальным кругом новой конструкции значительно ниже, чем шлифованных стандартным кругом. Это объясняется тем, что созданием прерывистости на фронтальной зоне рабочего торца с профилированием выступов по архимедовой спирали устраиваются периодические удары, увеличиваются число режущих зерен, создаются условия для относительно равномерного распределения между ними припуска и повышается выхаживающая способность сплошной части рабочего торца.

VIII. ВЫВОДЫ

1. Разработана новая конструкция торцового шлифовального круга с прерывистой режущей и сплошной выхаживающей частями рабочей поверхности, с переходом от впадин к выступам по архимедовой спирали. Характеристика архимедовой спирали представляет из себя сумму двух равномерных движений — поступательного в результате продольной подачи детали и вращательного, посредством вращательного движения шлифовального круга и практически обеспечивает постоянство угла атаки зерен, расположенных по всей ее длине. Предложенная конструкция торцового шлифовального круга была защищена в Государственном комитете по стандартизации метрологии и патентам и получен одноименный патент под № 0183.

2. Установлено, что созданием прерывистости в режущей - фронтальной зоне с переходом от выступа к впадине по архимедовой спирали и выполнением выхаживающей части рабочей поверхности торцового шлифовального круга сплошным, можно значительно повысить эффективности процесса шлифования, путем:
- снижения температурного воздействия на обрабатываемую поверхность;
- снижения шероховатости шлифованной поверхности;
- относительно равномерного распределения припуска на выступ между режущими абразивными зернами.
- снижения ударного воздействие на обрабатываемую поверхность и тем самым уменьшения вибраций технологической системы СПИД.

3. Путем реализации ортогонального плана второго порядка были получены математические модели зависимости показателей шероховатости шлифованной поверхности от параметров режима шлифования: скорости шлифования, скорости детали и глубины резания, при шлифовании как стандартным кругом, так и кругом новой конструкции.

4. Сравнительный анализ графических зависимостей полученных на основе эмпирических моделей показывает, что при применении новой конструкции торцового круга наблюдается значительное (до 30%) уменьшение шероховатости шлифованной поверхности. Применяемый метод экспериментальных исследований позволяет на основе полученных моделей изучить механизм формирования поверхностей, шлифованных кругом новой конструкции и оптимизировать его.

ЛИТЕРАТУРА

A Research Study to Determine if Solar Dryer Technology for Preservation of Agro-produce is needed in Botswana

By Ebangu Orari Benedict & Dintwa Edward

Abstract- High postharvest loss is a significant challenge to actors in the agro-produce value chain. The application of solar dryers for preservation of agro-produce has become an increasingly popular mitigation method for the high postharvest losses in sunny-belt countries. However, the adaptation of this technology is quite nascent in some of these countries. This study investigates if solar dryer technology is needed in Botswana. The methodology covered the assessment of the challenges faced by agro-dealers in Botswana and conducted a survey to determine the need for solar dryer technology for preservation of their agro-produce. Secondary and primary data were collected by means of literature and questionnaire administered using the opportunistic sampling method. The data was analysed using Statistics package for social scientists, SPSS computer program. The results established that there was need for solar dryer technology in Botswana for drying of produce to reduce postharvest losses.

GJRE-A Classification: FOR Code: 290501, 850506

Strictly as per the compliance and regulations of:
A Research Study to Determine if Solar Dryer Technology for Preservation of Agro-produce is needed in Botswana

Ebangu Orari Benedict* & Dintwa Edward*

Abstract- High postharvest loss is a significant challenge to actors in the agro-produce value chain. The application of solar dryers for preservation of agro-produce has become an increasingly popular mitigation method for the high postharvest losses in sunny-belt countries. However, the adaptation of this technology is quite nascent in some of these countries. This study investigates if solar dryer technology is needed in Botswana. The methodology covered the assessment of the challenges faced by agro-dealers in Botswana and conducted a survey to determine the need for solar dryer technology for preservation of their agro-produce. Secondary and primary data were collected by means of literature and questionnaire administered using the opportunistic sampling method. The data was analysed using Statistics package for social scientists, SPSS computer program. The results established that there was need for solar dryer technology in Botswana for drying of produce to reduce postharvest losses.

I. Introduction

The discussions on the various options for methods to alleviate the high global postharvest losses that negatively impact on agro-produce value-chain are on-going (Gbaha et al., 2007; Mujumdar, 2007). Recent research work has focussed on using renewable energy technologies for drying of agro-produce as possible preservation methods to reduce postharvest losses (Gustafsson et al., 2013). Solar dryers have increasingly become popular especially on account of their favourable relative costs of investment and operation. However solar dryers have not yet being adopted in Botswana despite the country’s endowment with abundant sunshine (Weiss and Buchinger, 2015). As part of an effort to intimately understand the challenges of the agro-producers and to establish the need for solar drying technology in the country, a survey was conducted. The study area for this survey was Gaborone and its environs. The survey targeted a cross section of stakeholders that included farmers, distributors, and retailers.

a) Research Questions

The main objective of this study was to assess the challenges being faced by stakeholders of agro-produce and to establish if there is need for solar dryer technology for preservation by drying. Hence, the survey was conducted to answer the following research questions:
1. Which are the agro-materials in need of preservation by drying in Botswana?
2. What are the challenges of preservation of agro-produce that are faced by agricultural communities of Botswana?
3. Is there a need for solar drying technology for agro-produce in Botswana?

b) Objectives

The specific objectives of this study were:
1. To establish the profile of agro-produce that are in need of preservation by drying in Botswana
2. To establish the challenges of preservation of agro-produce that are faced by agricultural communities of Botswana
3. To determine if there is need for solar dryer technology for agro-produce in Botswana.

II. Methodology

The research methodology used in the realisation of these objectives comprised of secondary data collection, primary data collection and data processing. The responses to social-demographic questions in the questionnaire that included name, sex, age, and education were of relevance for qualitative analysis; but providing name of respondent was optional and was not included in this analysis. Analyses using SPSS descriptive statistics and binary regression were performed.

a) Secondary data collection

Secondary data was obtained from journals, annual reports and general literature particularly from Botswana Ministry of Agriculture and Food Security. The data was used to profile the agro-produce in the country and additionally gave indication on the commercial trend of the agricultural enterprises.

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Author α: Department of Biosystems Engineering Gulu University, Gulu, Uganda.
b) Primary data collection

Primary data was obtained through a survey conducted in Botswana in June 2016 amongst targeted stakeholders. A questionnaire was administered, as the major tool for primary data collection distributed to various respondents who were contacted on voluntary basis. A variety of questions in the questionnaire were designed to collect data that would be analysed for the assessment of the need for solar dryer technology in Botswana as the intended purpose of the research study. The survey was conducted in Gaborone city and its environs including Mochudi and Mogoditshane.

c) Sampling methods

Four possible sampling methods for conducting the needs assessment survey were identified as: Random, Stratified, Systematic and Opportunity (Gamli, 2014; Sadeghi et al., 2013). The choice of a sampling method is based on the survey objectives and good representation of the target population. The execution time and accessibility of participants are the other important considerations. The Random, Stratified and Systematic Sampling methods apply probability-based sampling techniques whereas the Opportunity sampling method applies a non-probability-based sampling technique. The choice of the most appropriate sampling method for the study was made after analysing the opportunity cost of each of the four methods.

The Random Sampling method eliminates sampling bias, represents a target population but requires a great amount of time, effort and money. The chance of using the Random method in Gaborone was analysed. The target population in this survey was the consumer of the proposed solar drying technology in Botswana. The sample size corresponding to the population of Gaborone of 232,000 indigenous people by the 2013 national population census can be estimated. For a confidence level of \( n = 1.96 \) from the nominal tables corresponding to 95% confidence interval, error margin of 5% and proportion ratio of 0.5, assumed half of target population. The sample size determined would require using at least 385 respondents by the formula (Cochran, 2007):

\[
 n = \frac{Z^2 p(1-p)}{e^2} \tag{1}
\]

This would have required distribution of at least 1,153 questionnaires to potential respondents if the proportion of actual filled questionnaires was to be at least 30% of the total number of questionnaires distributed to the sample population. This is because of the high attrition rate (70%) that is associated with this type of survey (Barlett et al., 2001). To accomplish this exercise would have needed more research time and financial resources for implementation. Hence, the Random Sampling method was considered unsuitable for this research.

In Stratified Sampling, the weighted participation of the target population makes it highly representative, but costly in time, effort and money. The number of strata in respect of the objective of the questionnaire would be very large and difficult to organise so as to get a representative sample population of Gaborone and its environs. In view of the time required to perform stratification of the sampling frame, the Stratified Sampling method was not considered for use in this research.

The Systematic Sampling method uses defined participants with similar experiences and at same conditions and is representative of the target population. The method pre-supposes well-defined and identifiable participants of the sampling population, which is not practically possible. In view of the difficult task of establishing the sampling framework and the high expenses incurred in implementation of the task, the Systematic Sampling method could not be applied in this survey.

The Opportunity Sampling method, uses people from a target population, available at the time and willing to participate. It is based on convenience; it is quick and easy, but may be biased as the target population may not be very representative. This is the sampling method that was chosen for this study. To secure a representative population, the target population was identified and it was composed of all categories of agro-produce value-chain stakeholders, namely, agro-farmers, major distributors of agricultural products, wholesalers, and retail supermarkets and vendors. These were essentially independent participants who accepted to participate in the survey on voluntary basis.

d) Survey questionnaire

A questionnaire constituting 16 named/defined variables formulated as 16 questions was developed as given in Table 1. These variables comprised of the participant’s name, gender, age, education level, location, actor, produce handled, challenges faced, oversupply, preservation methods, drying problems, methods for improving preservation, need for solar drying technology, and suggestions by respondent for preservation of agro-produce. The questions that included name, sex, age, and education were of relevance for demographic analysis. Providing the name of the respondent was optional. The purpose for which each question in the questionnaire was meant to achieve has been provided.
Table 1: The named variables and their applications

<table>
<thead>
<tr>
<th>Variable</th>
<th>Code Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Not applied</td>
<td>Identification of participants by sex; males or females</td>
</tr>
<tr>
<td>Gender</td>
<td>Gender</td>
<td>Identification of participants by age group categories</td>
</tr>
<tr>
<td>Age</td>
<td>Age</td>
<td>Categorisation of participants according to classical education levels; University, Tertiary, Secondary, Primary and Non-formal</td>
</tr>
<tr>
<td>Education</td>
<td>Education</td>
<td>Categorisation of participants according to their areas of operation; Gaborone or Outside Gaborone</td>
</tr>
<tr>
<td>Location</td>
<td>Location</td>
<td>Categorisation of participants according to specific roles performed in agro-produce value chain; Farmer, Wholesaler, Retailor, Vendor</td>
</tr>
<tr>
<td>Actor</td>
<td>Actor</td>
<td>Identification of challenges experienced by participant in handling agro-produce after harvest</td>
</tr>
<tr>
<td>Produce</td>
<td>Produce</td>
<td>Establish agricultural produce handled by participant</td>
</tr>
<tr>
<td>Challenges</td>
<td>Challenges</td>
<td>Identification of challenges encountered in application of a drying method</td>
</tr>
<tr>
<td>Oversupply</td>
<td>Oversupply</td>
<td>Determination of methods currently used for preservation of agro-produce after harvest</td>
</tr>
<tr>
<td>Preservation Methods</td>
<td>PreservationM</td>
<td>Determination of methods currently used for preservation of agro-produce after harvest</td>
</tr>
<tr>
<td>Drying Methods</td>
<td>DryingM</td>
<td>Determination of methods currently used for drying of products</td>
</tr>
<tr>
<td>Drying Problems</td>
<td>DryingP</td>
<td>Identification of problems encountered in application of a drying method</td>
</tr>
<tr>
<td>Improvement</td>
<td>Improvement</td>
<td>Establish if respondent wants improvement in methods of postharvest preservation of agro-produce</td>
</tr>
<tr>
<td>Solar Technology Suggestions</td>
<td>SolarT</td>
<td>Determine if subject thinks solar technology is needed for preservation by drying</td>
</tr>
<tr>
<td></td>
<td>Suggestions</td>
<td>Get opinions on other methods of postharvest handling of agro-produce.</td>
</tr>
</tbody>
</table>

e) Data Processing

First, the secondary data was analysed to give the profile of agro-produce in Botswana categorised as horticultural products and grains and pulses. The challenges faced by the stakeholders were analysed with respect to the postharvest losses experienced in each agricultural enterprise. Secondly, analysis of the primary data that was collected from the responses to the questionnaire was accomplished with the aid of Excel and Statistics Package for Social Scientists, IBM SPSS® Version 20.

Table 2: Variable categories

<table>
<thead>
<tr>
<th>Demographic variables</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Nominal</td>
</tr>
<tr>
<td>Age</td>
<td>Ordinal</td>
</tr>
<tr>
<td>Education</td>
<td>Ordinal</td>
</tr>
<tr>
<td>Actor</td>
<td>Ordinal</td>
</tr>
<tr>
<td>Location</td>
<td>Nominal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produce</td>
<td>Ordinal</td>
</tr>
<tr>
<td>Challenges</td>
<td>Scale</td>
</tr>
<tr>
<td>Oversupply</td>
<td>Nominal</td>
</tr>
<tr>
<td>PreservationM</td>
<td>Ordinal</td>
</tr>
<tr>
<td>DryingM</td>
<td>Ordinal</td>
</tr>
<tr>
<td>DryingP</td>
<td>Scale</td>
</tr>
<tr>
<td>Improvement</td>
<td>Scale</td>
</tr>
<tr>
<td>SolarT</td>
<td>Nominal</td>
</tr>
<tr>
<td>Suggestions</td>
<td>Ordinal</td>
</tr>
</tbody>
</table>
SPSS models were applied in the analysis: Descriptive statistics was applied for evaluation of frequency/percentages of variable occurrences. This was to give the statistics of the variable responses. Descriptive statistics and cross-tabulation were applied for teasing out demographic participants. Some variables were considered as predictor variables because of their relevance to precise prediction of solar drying as a method of preservation to be used in Botswana. The predictor variables were:

1. Preservation methods, PreservationM, that asked if the respondent wants to improve upon the preservation methods being used;
2. The drying methods, DryingM, that asked if the respondent wants to improve the drying method they are already using
3. The drying problems, DryingP, that asked if there were challenges or disadvantages associated with the respondent’s method of drying the products
4. The solar technology SolarT, that asked if the respondent thought that solar drying technology is needed for preservation of agricultural products in Botswana.

Descriptive statistics and cross-tabulations of these variables was done with the socio-demographic variables that comprised of

1. Gender that asked if the participant was female or male
2. Age asked for the number of years the participant has lived
3. Education asked for level of education attained by the participant,
4. Actor, asks for the agri-business role played by each respondent in the sample population in the agro-produce value-chain.

Binary logistic regression was applied in the prediction of likelihood of adaptation of solar drying technology in Botswana. Logic codes 0, 1, are used in the coding of nominal variables, $Y_i$ expressed in binary format given as $1=$ agree and $0=$ disagree. The linear regression model for the odds probability expressed as, $P(Y_i = y_i) = \pi_i$ is not sustainable because of overflow of values on the right hand side of the equation comprising of covariant and regression coefficient $\beta$ that exceed the boundary conditions of the probability domain (of 0-1). Hence the creation and transformation of the odds ratio $\eta_i$ to a linear model by taking its natural logarithm, thus resulting into Logit model which opens the boundary restrictions to limits of $-\infty$ to $+\infty$. The odds ratio $\pi$ is expressed as

$$\pi_i = \frac{p_i}{1 - p_i} \quad (2)$$

Where $p_i$ is the instantaneous probability of the covariant.

The Logit model is expressed as

$$\logit = \log (\pi) = \log \left( \frac{p_i}{1 - p_i} \right) \quad (3)$$

Thus the generic multivariate logistic binomial distribution model is given as

$$\eta_i = \beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n \quad (4)$$

Where $n$ is the number of occurrences, $x_i$ are the independent variables, and $\beta_i$ are the binomial coefficients.

The probability is evaluated by

$$p_i = \frac{\exp(\eta_i)}{1 + \exp(\eta_i)} \quad (5)$$

Logit model is the binary model used to predict likelihoods of occurrences by applying a stochastic approach. The SPSS Regression and Binary Logistic model was applied in this analysis to predict the likelihood of adaptation of solar drying technology, Solar T, for preservation of agricultural products in Botswana using five variables that were considered to have great influence over such outcome. The identified variables were Gender, Actor, Oversupply, Drying M, and Produce. These variables were identified as categorical; nominal, ordinal dependent variables and were coded accordingly. The dependent variable encoding is as given in Table 3.

<table>
<thead>
<tr>
<th>Original Value</th>
<th>Internal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disagree</td>
<td>0</td>
</tr>
<tr>
<td>Agree</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4 is the classification table of the observed and predicted likelihoods of adapting solar dryer technology, SolarT, in Botswana. Table 5 presents the notations used to describe the classification cases.

$$Table 3: \text{Dependent Variable Encoding}$$

<table>
<thead>
<tr>
<th>Observed dichotomous variable, Solar T</th>
<th>Predicted</th>
<th>Percentage correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disagree</td>
<td>TN</td>
<td>ON</td>
</tr>
<tr>
<td>Agree</td>
<td>FN</td>
<td>TP</td>
</tr>
<tr>
<td></td>
<td>PN</td>
<td>PP</td>
</tr>
</tbody>
</table>
The overall accuracy of the logistic regression model is measured from the fit of the model. The accuracy of the model prediction is its likelihood of occurrence calculated using the relationship

$$\text{Likelihood} = \frac{Tupp}{Tot} = \frac{(TN+TP)}{(TN+TP+FN+FP)}$$

(6)

### Table 5: Case Notations

<table>
<thead>
<tr>
<th>Case</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN</td>
<td>True negative</td>
</tr>
<tr>
<td>FN</td>
<td>False negative</td>
</tr>
<tr>
<td>FP</td>
<td>False positive</td>
</tr>
<tr>
<td>TP</td>
<td>True positive</td>
</tr>
<tr>
<td>PN</td>
<td>Predicted-Negative= $TN+FN$</td>
</tr>
<tr>
<td>PP</td>
<td>Predicted-Positive= $FP+TP$</td>
</tr>
<tr>
<td>ON</td>
<td>Observed-Negative= $TN+FP$</td>
</tr>
<tr>
<td>OP</td>
<td>Observed-Positive= $FN+TP$</td>
</tr>
<tr>
<td>Tot</td>
<td>Total cases= $TP+FP+FN+TN$</td>
</tr>
<tr>
<td>Tupp</td>
<td>Total true cases= $TN+TP$</td>
</tr>
</tbody>
</table>

III. Results and Discussions

a) Horticultural agro-products

This study clearly shows that a large variety of horticultural produce is grown in Botswana. The produce includes cabbage, broccoli, green peas, garden peas, mustard, tomato, chillies, rape, Swiss-chard, choumoliver, onion, egg-plant, butter nut, courgettes, green mealies, water melons, beetroot, carrots, herbs, green pepper, potatoes, and mango (MoA, 2012). However, some horticultural produce is imported from neighbouring countries, particularly South Africa, to bridge the local supply gaps. The cumulative production and cumulative sales for the produce commodities in the month of March 2015 is presented in Figure 1 which shows the cumulative production in metric tonnes versus cumulative sales in Pula. The trend of commodity transactions on horticultural produce in Botswana for March 2015 indicated that products of highest commercial significance were tomatoes, potatoes, cabbage, beetroot and onions.

![Horticulture trend (March 2015)](image)

Figure 1: The trend of Horticultural Production in Botswana, March 2015 (MoA, 2012)

The production growth rate is depicted in Figure 2. It shows that the growth rate of production of horticulture increased from 20% in 2014 to 60% in 2018. This is a positive trend for the country.

![Production growth rate %](image)

Figure 2: The production growth rate of horticultural products (MoA, 2012)
b) Grains and pulses

Figure 3 depicts the result of performance of grains and pulses analysed from the data obtained during the period 2007-2012. Botswana’s crops of commercial and economic significance in the category of grains and pulses were sorghum, maize, pulses and sunflower. These are staple food crops for most households in Africa. Botswana is a net food importing developing country (NFIDC). Sorghum and maize are the main cereals, the basic foodstuffs with their national demand standing at 200,000 metric tons per year, of which only 17% is supplied through local production (BITC, 2019). The demand gap of 83% was met by importation from other countries.

![Figure 3: Five-year production trend, 2007-2012, for grains and pulses in Botswana (MoA, 2012)](image)

Figure 3: Five-year production trend, 2007-2012, for grains and pulses in Botswana (MoA, 2012)

c) Challenges faced by agro-produce value-chain actors

The challenges faced by the agricultural communities of Botswana are categorized as: i) postharvest losses on agro-produce and ii) preservation of the agro materials after harvest.

i. Postharvest losses of agro-produce

The ranking of average losses of agro-produce in Botswana in 2015 is depicted in the pie chart of Figure 4. Tomatoes posted the highest loss of 28%, followed by spinach at 18%, sorghum at 16% and maize at 14%. It is clear from the pie chart that the main grains (sorghum and maize) constitute 30% and the horticultural produce constituted 70% of the postharvest losses of agro-produce in Botswana. The spoilage percentages obtained from the respondents indicated varying losses for the different commodities with some agro-produce incurring more losses than others. The horticultural products were found to be generally the more perishable commodities. Tomato and spinach were overall the highest ranked in postharvest losses of agro-produce in Botswana.

![Figure 4: The postharvest loss ranking of the common Botswana agro-produce in 2015](image)
ii. The challenges of preservation of agro-produce after harvest

Table 6 gives the summary of challenges faced by the farming community of Botswana with regard to agro-produce handled and preservation methods used. The level of each challenge was rated as either low or both high. One of the major challenges encountered was that of quality deterioration issues and oversupply during the harvest season and low supply otherwise, resulting in loss of the produce, and by extension, income. Preservation challenges included inaccessibility of conventional technologies in rural locations and the high cost of the technologies. The open sun method, while cheap, has a major challenge of difficulties in assuring the quality of the products, due to a variety of factors such as long drying times, contamination due to exposure to the environment, encroachment by pests and vermin, as well as uncontrolled drying rates. These challenges indicated the need for alternative methods using affordable technologies such as solar based technologies, to improve on the existing methods.

<table>
<thead>
<tr>
<th>Item</th>
<th>Challenges</th>
<th>Rating of challenge</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agro-produce</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oversupply</td>
<td>✓</td>
<td>✓</td>
<td>Loss of value</td>
</tr>
<tr>
<td>Quality deterioration</td>
<td>✓</td>
<td>✓</td>
<td>Non/Perishability</td>
</tr>
<tr>
<td>Storage facilities</td>
<td>✓</td>
<td></td>
<td>Lacking in rural settings</td>
</tr>
<tr>
<td>Transport</td>
<td>✓</td>
<td></td>
<td>Inappropriate</td>
</tr>
<tr>
<td><strong>Conventional preservation methods</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality of product</td>
<td>✓</td>
<td></td>
<td>Limited shelf-life</td>
</tr>
<tr>
<td>Availability</td>
<td>✓</td>
<td></td>
<td>Inaccessible in rural settings</td>
</tr>
<tr>
<td>Cost</td>
<td>✓</td>
<td>✓</td>
<td>High investment</td>
</tr>
<tr>
<td><strong>The open sun drying method</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality of product</td>
<td>✓</td>
<td>✓</td>
<td>Not quality assured</td>
</tr>
<tr>
<td>Availability</td>
<td>✓</td>
<td></td>
<td>Intermittent</td>
</tr>
<tr>
<td>Cost</td>
<td>✓</td>
<td>✓</td>
<td>Free but affected by weather</td>
</tr>
<tr>
<td><strong>Solar dryer</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low awareness</td>
<td>✓</td>
<td></td>
<td>Not disseminated</td>
</tr>
<tr>
<td>Non availability</td>
<td>✓</td>
<td></td>
<td>Nascent technology</td>
</tr>
<tr>
<td>Cost of technology</td>
<td>✓</td>
<td>✓</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

d) Need for solar dryer technology in Botswana

The analysis of the data to establish the need for solar drying technology in Botswana was performed with the help of the SPSS Statistics package (Version 20, developed by IBM Corporation, Corporate headquarters, 1 New Orchard Road, Armonk, New York 10504-1722 USA). The results were categorized as Demographic statistics, Cross Tabulation statistics and Likelihood estimates.

i. Demographic statistics

Figure 5 shows the responses according to gender. The total number of responses was 32 and comprised of 17 males and 15 females. Demographic statistics showed that there was fairly good gender balance with 46.9% female and 53.1% male.

![Figure 5: The pie chart of gender classification](image)
Figure 6 shows the responses according to age group. All the respondents were of adult age above 20 years old and comprised of 37.5% of age group 20-25 years; 25% of 26-30 years; 18.8% being of the 31-35 year’s group; and, 18.8% being of the group above 35 years. The youthful age group of 20-25 years was highest.

![Figure 6: The pie chart according to age groups](image)

Figure 7 shows the education level of the respondents. All of the respondents were literate and understood the English language that was used in the questionnaire. By education, 40.6% of the respondents were of university level, 21.9% college level, 21.9% Secondary school level, 12.5% primary school level and 3.1% non-formal education. The highest number of respondents was of University level education.

![Figure 7: The responses according to education levels](image)

Figure 8 shows the location of respondents. All the respondents were located in Botswana with 68.8% of the respondents coming from Gaborone City and 31.2% from Gaborone environs.

![Figure 8: The responses according to location](image)
Figure 9 gives the responses to the questions about the preservation methods presently used for preservation of agricultural products in Botswana. Various methods of preservation of agricultural products are used by respondents of whom 25% were drying agricultural products, 28.1% cooking, 28.1% freezing, 3.1% bottling and 15.6% used other preservation methods. The method of refrigeration/chilling was highest and was followed by drying and cooking.

An overwhelming majority (84.4%) of the respondents agreed that the use of solar technology, SolarT, could be the better method for preserving their produce while 15.6% did not agree as depicted in Figure 10.

The result indicates the responses of Actor variable are: 37.4% for Farmer, 6.3% for Distributor, 18.8% for Retailer, 25% for Vendor, and 12.5% for Consumer. The farmer had the highest respondents, signifying the most agreeing stakeholder in the survey as depicted in Figure 11.
ii. Cross-tabulation statistics

The results of the cross-tabulation model analysis show that out of the total 32 respondents, 8 responded to the question on typical methods of preservation; 11 responded to the question on the drying methods used; 12 responded to the question regarding problems encountered with the drying method used; and 27 responded to the question on the need for solar drying technology.

The results of the cross-tabulations of Gender are presented in Table 7. The results indicate that of the 8 respondents for the variable PreservationM, 5 were females and 3 were males. For the variable DryingM, 7 out of the 11 respondents were males; and for DryingP, 5 of the 12 respondents were females and 7 were males. Further, the cross-tabulation of the SolarT variable with Gender indicated that of the 27 respondents, 12 were females and 15 were males.

Table 7: Cross-tabulation of drying variables with Gender

<table>
<thead>
<tr>
<th>Variables</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>PreservationM=8/32</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>DryingM=11/32</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>DryingP=12/32</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>SolarT =27/32</td>
<td>12</td>
<td>15</td>
</tr>
</tbody>
</table>

The cross-tabulation model results of drying variables with Age. It was observed that the age group 20-25 years was the highest represented in all the four variables: 5 out of 8 for PreservationM; 4 out of the 11 respondents for DryingM; 4 out of the 12 respondents for Drying P; and 9 out of the 27 respondents for SolarT.

Table 8: Cross-tabulation of drying variables with Age

<table>
<thead>
<tr>
<th>Variables</th>
<th>20-25-25yrs</th>
<th>21-30</th>
<th>31-35</th>
<th>35+</th>
</tr>
</thead>
<tbody>
<tr>
<td>PreservationM=8/32</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>DryingM=11/32</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>DryingP=12/32</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>SolarT =27/32</td>
<td>9</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

The cross-tabulation model results for Education with the drying variables are given in Table 9. The table shows that for all the four variables, the level of education with the highest number respondents was University Level. The highest number, 4 out of 8 of respondents for Preservation M were of university level, while for Drying M it was 5 out of 11. Of the 12 respondents of Drying P, University level was again highest with 6 respondents. Finally, of the 27 respondents of Solar T variable, University level was highest with 12.

Table 9: Cross-tabulation of drying variables with Education

<table>
<thead>
<tr>
<th>Variables</th>
<th>University</th>
<th>College</th>
<th>Secondary</th>
<th>Primary</th>
<th>Non-formal</th>
</tr>
</thead>
<tbody>
<tr>
<td>PreservationM=8/32</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>DryingM=11/32</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>DryingP=12/32</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>SolarT =27/32</td>
<td>12</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

The cross-tabulation results for Actor are given in Table 10. As shown, of the 14 respondents of Preservation M, 6 of the respondents were retailers, followed by farmers at 5 respondents; and the distributor, vendor and consumer at 1 respondent each. Of the 12 respondents of Drying M, 4 were Farmer, Distributer, Retailer and Consumer were each at 2 respondents and Vendor received 1 respondent. Of the 12 respondents of the Drying P, Farmer was the highest with 6 out of the 12 respondents; followed by Distributer and Consumer with 2 respondents each. Finally, of the 27 respondents of Solar T, 11 were farmers, 6 were vendors, 4 were retailers/consumers while 2 respondents were distributors.

Table 10: Cross-tabulation of drying variables with Actor variable

<table>
<thead>
<tr>
<th>Variables</th>
<th>Farmer</th>
<th>Distributer</th>
<th>Retailer</th>
<th>Vendor</th>
<th>Consumer</th>
</tr>
</thead>
<tbody>
<tr>
<td>PreservationM=14/32</td>
<td>5</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>DryingM=11/32</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>DryingP=12/32</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>SolarT =27/32</td>
<td>11</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

iii. Likelihood estimates

The results of the binomial regression using logic model are given in the Classification Table 11 whereby the overall percentage of likelihood is predicted as 87.5%.
Table 11: The Classification Table

<table>
<thead>
<tr>
<th>Observed</th>
<th>Predicted</th>
<th>Percentage correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SolarT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disagree</td>
<td>Agree</td>
</tr>
<tr>
<td>SolarT</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Agree</td>
<td>1</td>
<td>26</td>
</tr>
</tbody>
</table>

Overall percentage 87.5

a = the cut off value of overall percentage is 50%

Table 12 shows the results of the predictor variables evaluated using Equation 4, depicting respective binomial regression terms. These predictor variables include the constant term. The variables are characterised by the binomial regression coefficient $\beta$, standard error (S.E), estimate of the regression coefficient divided by its standard error defined as Wald. The one degree of freedom, $d_f$, for the standard normal distribution, the significance, $p$-values that are statistically significant except for the constant term which is below 0.05. The odds ratio probability ($\eta$) is expressed as $\text{Exp } \beta$, for each variable. The confidence intervals (95% C.I), depicting lower and upper values for each variable are expressed in terms of the odds ratio values $\text{Exp } \beta$.

Table 12: The Results of Binominal Regression

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\beta$</th>
<th>SE</th>
<th>Wald</th>
<th>$d_f$</th>
<th>$P$-value</th>
<th>Exp $\beta$ with 95% C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>0.229</td>
<td>1.306</td>
<td>0.031</td>
<td>1</td>
<td>0.861</td>
<td>1.257 (0.097, 16.269)</td>
</tr>
<tr>
<td>Actor</td>
<td>0.564</td>
<td>0.613</td>
<td>0.847</td>
<td>1</td>
<td>0.357</td>
<td>1.757 (0.529, 5.837)</td>
</tr>
<tr>
<td>Produce</td>
<td>-0.805</td>
<td>0.488</td>
<td>2.72</td>
<td>1</td>
<td>0.099</td>
<td>0.447 (0.172, 1.164)</td>
</tr>
<tr>
<td>Oversupply</td>
<td>-3.512</td>
<td>1.881</td>
<td>3.485</td>
<td>1</td>
<td>0.062</td>
<td>0.03 (0.001, 1.192)</td>
</tr>
<tr>
<td>DryingM</td>
<td>1.06</td>
<td>1.403</td>
<td>0.57</td>
<td>1</td>
<td>0.45</td>
<td>2.885 (0.184, 45.138)</td>
</tr>
<tr>
<td>Constant</td>
<td>5.199</td>
<td>2.544</td>
<td>4.175</td>
<td>1</td>
<td>0.041</td>
<td>181.059</td>
</tr>
</tbody>
</table>

From the Table 12, the odds ratio is >1 for Drying M, Actor and Gender but <1 for Produce and Oversupply variables. Therefore, Drying M, Actor and Gender are key parameters in motivating the likelihood of acceptance of solar drying technology. Using Equation 4, the Logit model for this study that fits the regression data for giving an estimated evaluation of the probability of accepting solar dryer technology in Botswana is given as

\[
\logit = \log \left( \frac{\pi_i}{1 - \pi_i} \right) = 5.199 + 1.06 * \text{DryingM} + 0.564 * \text{Actor} + 0.229 * \text{Gender} - 0.805 * \text{Produce} - 0.512 * \text{Oversupply}
\]

IV. Conclusion

The determination of the need for solar dryer technology in Botswana was satisfactorily accomplished. The assessment provided answers to the questions of agro-produce profile that need to be preserved by solar drying, the challenges encountered by the agricultural communities and the determination of whether there was need for a solar dryer technology in Botswana as follows:

The profile of agro-produce grown in Botswana covers a limited range of grains and pulses and a large variety of horticultural produce despite being a semi-arid country. There was a positive trend of production of horticultural produce in Botswana for March 2015 with tomatoes, potatoes, cabbage, beetroot and onions as the top commercial commodities. However, Botswana is a net food importing developing country. Sorghum and maize are the main cereal foodstuffs with their national annual demand of 200,000 metric tons, of which only 17% was supplied through local production while the supply demand of 83% was met by importation from other countries in 2019. The overall postharvest loss distributions were: i) the main grains (sorghum and maize) constituted 30%, and ii) horticultural produce constituted 70%. Tomato posted the highest loss ranking of 28%, followed by spinach at 18%, sorghum at 16% and maize at 14%. The loss ranking clearly showed that tomato was the most in need of preservation by drying.

The greatest challenge faced by actors in agro-produce value-chain is the postharvest loss. Moreover,
conventional preservation methods are generally unaffordable by the poorer rural communities. These communities often use the inappropriate methods of preservation such as the open sun drying method which is not quality assured. And yet solar dryer technology is scarce in Botswana.

The study answered the question of whether there was need for solar dryer technology in Botswana. Demographic statistics indicated 84.4% acceptance of solar dryer technology in Botswana. Additionally, there was fair gender balance with the youthful age bracket (20-25 years), university level education, and the farmer among the actors; these were identified as the highest respondents in favour of solar drying technology; indicating the sustainability of the technology when adapted. The study has established that there is need for solar drying technology in Botswana and, by the Logit model, predicted that the likelihood of acceptance of the technology was 87.5%.

Acknowledgement

The authors greatly acknowledge the funding by Education, Audio-visual and Culture Executive Agency, EACEA of the European Commission, which is the sponsor of the project entitled Mobility to Enhance Training of Graduate Engineers in Africa, METEGA for providing the scholarship for the PhD research; Additional support by RUFORUM, University of Botswana (ORD) and Gulu University is highly appreciated.

References

Machine Reliability Optimization by Genetic Algorithm Approach

By Ngnassi Djami Aslain Brisco, Nzie Wolfgang & Doka Yamigno Serge

University of Ngaoundere

Abstract: To define the reliability network of a system (machine), we start with a set of components arranged in an appropriate topology (series, parallel, or parallel-series), choose the best terms of the ratio performance / cost, and gather by links with the aim to combine them. This process requires a long time and effort, given the very large number of possible combinations, which becomes tedious for the analyst. For this reason, it is essential to use an appropriate optimization approach when designing any product. However, before trying to optimize, it is necessary to have a reliability assessment method. The objective of this paper is to display a meta-heuristic method, which is sustained on the genetic algorithm (GA) to improve the machines reliability. To achieve this objective, a methodology that consists of presenting the functionalities of genetic algorithms is developed. The result achieved is the proposal of a reliability network for the optimal solution.

Keywords: reliability, cost, reliability network, topology.

GJRE-A Classification: FOR Code: 091399

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Machine Reliability Optimization by Genetic Algorithm Approach

Ngnassi Djami Aslain Brisco, Nzie Wolfgang & Doka Yamigno Serge

Abstract: To define the reliability network of a system (machine), we start with a set of components arranged in an appropriate topology (series, parallel, or parallel-series), choose the best terms of the ratio performance / cost, and gather by links with the aim to combine them. This process requires a long time and effort, given the very large number of possible combinations, which becomes tedious for the analyst. For this reason, it is essential to use an appropriate optimization approach when designing any product. However, before trying to optimize, it is necessary to have a reliability assessment method. The objective of this paper is to display a meta-heuristic method, which is sustained on the genetic algorithm (GA) to improve the machines reliability. To achieve this objective, a methodology that consists of presenting the functionalities of genetic algorithms is developed. The result achieved is the proposal of a reliability network for the optimal solution.

Keywords: reliability, cost, reliability network, topology.

I. INTRODUCTION

The fundamental function of a system is to provide its customers with a fairly economical cost, acceptable reliability required. These constraints require an optimal design. In the engineering context, the fundamental interest of manufacturers is to find a balance between the reliability of a system and its cost. These two factors constitute the most important decision variable for optimizing a system. This is generally manifested in minimizing the cost under the constraint of reliability on the one hand, and in improving performance to meet the needs of customers under the constraint of cost on the other.

In this area, researchers have developed and improved many methods and algorithms. The set of methods can be divided into two main categories: exact methods, which guarantee to obtain an optimal solution for problems of reasonable size, and approximate methods (heuristics and meta-heuristics), which give good solutions. Quality, without guarantee of optimality, but for the benefit of shorter calculation time.

II. THE FUNCTIONING OF THE GENETIC ALGORITHM

a) Origin and principle

Genetic algorithms (GA) are heuristic optimization algorithms based on the principles of natural selection and genetics. The researcher Rechenberg [3], is the first scientist who introduced evolutionary algorithms by publishing his work "Evolution strategies." These algorithms are broadly inspired by Darwin's theory of evolution published in 1859. Next, Holland [4] proposed the first genetic algorithms to solve combinatorial optimization problems, and they were also developed by the work of David Goldberg published in 1989 (Goldberg [5] and Goldberg [6]).

The aim of the genetic algorithm is to bring up, from one generation to another, the candidates (potential solutions) most suited to solving the problem. Each generation is made up of a defined number of individuals, these form a population, and each of them represents a point in the search space. Each individual (chromosome) has information coded in the form of a...
chain of characters that analogically constitutes genes. Then the passage from one generation to another is carried out based on the process of evolution by the use of evolutionary operators like selection, crossing, and mutation.

Their operating principle is quite simple. From an initial population created at random, composed of a set of individuals (chromosomes), we proceed to the evaluation of their parent qualifications to highlight the best suited, as long as the least effective are rejected. Then, the most qualified individuals are chosen by privileged selection by giving them a chance to reproduce by crossing and mutating via the two operators of crossing and mutation. Then by relaunching this process several times, the optimal solution can be refined by passing from one generation to another (Douiri et al. [7]).

b) Description of the formalism used

Clustering is a process that partitions a set of data into meaningful subclasses (clusters or clusters).

The convergence of genetic algorithms has been demonstrated for many problems, although optimality cannot be guaranteed. The ability of a genetic approach to find the right solution often depends on the adequacy of the coding, the evolution operators, and the measures of adaptation to the problem being addressed. The method proposed here is based on genetic algorithms (Goldberg [6]) and evolutionary strategies (Schewefel [8]). It combines the principle of survival of the ablest individuals and genetic combinations for an elitist research mechanism. The genetic method produces new solutions (children) by combining existing solutions (parents) selected from the population, or by mutation. The central idea is that parent solutions will tend to produce superior child solutions in terms of adaptation so that ultimately a solution obtained is optimal.

In this study, we used a genetic method previously defined by Bicking et al. [10] with a definition of the chromosome and the operators of selection, combination, and mutation concerned. Unlike genetic algorithms, the genetic method used is designed to minimize and not maximize. This method, like genetic algorithms, is not limited by assumptions about the objective function and research space, such as continuity or differentiability. It uses a population of points simultaneously by contrast with usual methods using only one point. Genetic operators are elitistically improving the search process to find the global optimum. There are more complicated genetic operators, but the basic operators and their various modifications can generally be applied. The choice of these operators depends on the nature of the problem and the performance requirements. The genetic algorithm that we are going to implement is as follows, where the process is applied to iteration :k:

1. Data coding;
2. Generation of the initial population \( P_0 \) of \( N \) individuals;
3. Assessment of the adaptation of all individuals in the population;
4. Selection of a proportion of the best individuals (parents for the production of new individuals);
5. The Crossing of all individuals in the population \( P_k \) two by two with a probability \( P_m \), we will have \( N \) children noted \( C_k \);
6. Mutation of all individuals in the population, we will have \( N \) elements noted \( M_k \);
7. Choice of the most suitable individuals, i.e., those who optimize the objective function;
8. If the stop test is verified, stop, otherwise return to step a.

We will choose, as a stop test in our implementation, a finite number of iterations.

It is important to note that the stopping criterion can be several cycles of the algorithm (number of generations), the average of the adaptations of individuals, a convergence factor, etc.

An individual represents a vector of decision variable (parameters), and its adaptation is measured by the objective function. The formalism and the genetic operators are detailed below.

i. Data coding

The first step is to properly define and code the problem. That step associates with each point of the search space a specific data structure called a chromosome, which will characterize each individual in the population. This step is considered to be the most important step in GA because the success of these algorithms depends heavily on how individuals are coded.

There are different choices for coding a chromosome, this choice being a very important factor in the progress of the algorithm so it must be well suited to the problem being addressed:

- Binary coding: It is the most used coding. The chromosome is coded by a string of bits (which can take the value 0 or 1) containing all the information necessary to describe a point in space;
- Multi-character coding: this is often more natural. We are talking about multiple characters as opposed to bits. A chromosome is then represented by a series of numbers or characters, each representing a gene;
- Coding in the form of a tree: this coding in tree structure starts from a root (comprising several parts equal to the number of initial individuals), from which one or more children can be derived. The tree then builds up gradually, adding branches to each new generation.
ii. Generation of the initial population

Each chromosome is the potential result of the optimization problem. We define a chromosome as a chain composed of genes, which are the parameters (decision variables) to find. The value of a gene is called an allele. The possible value of an allele is an integer or a real value. Each gene is created randomly, using equation 1.

$$ a_j = (a_j)_i + ((a_j)_u - (a_j)_i) \times \gamma_j $$

Where:

- \( \gamma_j \in \{0; 1\} \) is chosen randomly
- \( (a_j)_i, (a_j)_u \) are the minimum and maximum limits of the allele \( a_j \). They are chosen according to the problem to be treated.

Each chromosome, called an individual in a haploid representation, can be written:

$$ X_i = [a_1, ..., a_j, ..., a_m] $$

With:

- \( m \) is the number of genes
- \( i = 1, ..., N \) and \( N \) is the size of the population (number of individuals).

All the constraints are taken into account in the initial phase of population creation. When an individual is created, if the constraints are respected, this individual is integrated into the initial population; otherwise, it is not. At the start of the algorithm, the initial population contains individuals.

The length of the chromosome \( m \) and the size of the population \( N \) is two of the four adjustment parameters of the genetic method.

iii. Objective function and adaptation

We evaluate the different solutions proposed to treat them according to their relevance and to see which the best are. For this, we use the objective function.

This function measures the performance of each individual. To be able to judge the quality of an individual and thus compare him to others. The objective function of our case is to minimize the cost while maximizing reliability.

The evaluation of each individual in the population then makes it possible to make the selection. For a system made up of \( n \) components in parallel, the reliability to be maximized is given by equation 2.

$$ R = 1 - \prod_{i=1}^{n} (1 - r_i) $$

Where:

- \( n \) is the number of components
- \( r_i \) is the reliability of the component \( i \)

For a parallel-series system, the reliability to be maximized is given by equation 3.

$$ C = \sum_{i=1}^{n} C_i \left[ X_i + e^{X_i/4} \right] $$

Where:

- \( C_i \) is the cost vector of the components of the \( X_i \) chromosome
- \( p \) is the number of stages of the machine.

iv. Selection of the most suitable individuals

When the entire population is assessed at generation \( t \), individuals are ranked in ascending order of objective function. Then the selection is made. Selection helps to statistically identify the best individuals in a population and eliminate the bad ones from one generation to the next. This operator also gives a chance to the bad elements because these elements can, by crossing or mutation, generate relevant descendants compared to the optimization criterion.

The first \( N \times G \) individuals (the best \( N \times G \)) are selected to be parents. \( G \) is the third setting parameter of the genetic method. \( G \) is called the generation gap. \( G \) makes it possible to select a part of the population to provide sufficient genetic material without decreasing the speed of convergence (Goldberg [6]).

There are different selection techniques:

- Selection by rank: This selection method always chooses the individuals with the best adaptation scores, without allowing chance to intervene;
- Selection by wheel: For each parent, the probability of being selected is proportional to their adaptation to the problem (their score by the fitness function). This selection be imaged by a casino roulette wheel, on which all the chromosomes of the population are placed, the place is given to each of the chromosomes being proportional to its adaptation value. Also, the higher an individual's score, the more likely he is to be selected. We spin the wheel as many times as we want individual sons. The best will be able to be drawn several times, and the worst never;
- Selection by tournament: Two individuals are chosen at random, their adaptation functions are compared, and the best suited is selected;
- Uniform selection: We are not interested in the adaptation value of the objective function, and the selection is made in a random and uniform manner.
such that each individual has the same probability $P(i) = 1/N$ as all other individuals, where $N$ is the total number of individuals in the population;

- Elitism: The passage from one generation to another through the crossing and mutation operators creates a great risk of losing the best chromosomes. Therefore, elitism aims to copy the best (or first - best) chromosome(s) from the current population to the new population before proceeding to the mechanisms of crossing and mutation. This technique quickly improves the solution because it prevents the loss of the most qualified chromosome when passing from one generation to another.

v. Crossing

The selected population is divided into $N/2$ couples formed randomly. Two parents, and are chosen randomly from the potential parents $P_1$ and $P_1$ their genes are combined according to equation 5.

$$a_j(k) = a_j(P_1) + (a_j(P_2) - a_j(P_1)) \times \gamma_j$$  \hspace{1cm} (5)

Where:
- $\gamma_j$ is a uniform random number,
- $k = N \times G + 1, \ldots, N$, the $k$ th individual, mode can
- $j = 1, \ldots, m$.

The newly created individual is then evaluated. If its adaptation is better than that of the worst parent, it is integrated into the population to training the next generation. If it is not the case, we repeat the combination.

vi. Mutation of all individuals in the population

The mutation operator is a process where a minor change in the genetic code is applied to an individual to introduce diversity and thus avoid falling into local optima. This operator is applied with a probability $P_m$. $P_m$ generally lower than that of the crossing $P_c$. This probability must be low. Otherwise the GA will turn into a random search.

vii. Choosing the best solutions

This choice consists in retaining the solutions which have a lower value of the objective function, and putting them in the population $P_{k+1}$.

viii. Stopping criterion

The stopping criterion is evaluated in the current population. If it is filled, the whole population has converged on the solution. Otherwise the reproduction pattern will be repeated. The stopping criterion used in this method expresses that all individuals have converged on the same solution and assumes that evolution is no longer possible, that is to say, that no better solution can be found.

The whole strategy is elitist because only the best individuals are selected for survival from one generation to the next and can be the parents of new and better individuals. To ensure convergence of the algorithm, the parameters $N$ and $G$ must be adjusted with care. The size of the population $N$ affects both the performance and efficiency of the algorithm (Bicking et al. [10]). The algorithm is less efficient with very small population sizes. Large population size may contain more interesting solutions and discourage premature convergence towards sub-optimal solutions, but requires more assessments per generation, which can lead to a low convergence rate. The generation gap $G$ determines the proportion of the population that remains unchanged between two generations.

It is chosen to select individuals as severely as possible, without destroying the diversity of the population too much. The global strategy used assumes that all the individuals who make up the population, from generation to generation, satisfy all the constraints.

The best solution for the latest generation represents the solution to the problem by the defined criteria.

III. Application

Consider a machine made up of five components mounted in parallel (see Figure 1). Our goal is to define an optimal reliability network, to ensure operation with minimum reliability $r_{\text{min}} = 0.80$ while minimizing the cost of the structure.

![Figure 1: Structure (machine) to optimize](image)

Table 1 groups the parameters of the five components $C_1$, $C_2$, $C_3$, $C_4$ and $C_5$.

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<th>Reliability</th>
<th>Cost</th>
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<td>$C_1$</td>
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<td>$C_2$</td>
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<td>17</td>
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<td>$C_3$</td>
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</tr>
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<td>12</td>
</tr>
<tr>
<td>$C_5$</td>
<td>0.96</td>
<td>16</td>
</tr>
</tbody>
</table>

Step 1: Data coding

We choose binary coding using a 5-bit character string. Bits 1 through 5 represent the components of $C_1$ through $C_5$, respectively. If a component exists in the generated solution, then its
corresponding bit takes the value "1"; otherwise, it takes the value "0".

**Step 2: Choice of GA parameters**
This choice is random while waiting to improve it afterward. The parameters of the GA are as follows:
- The size of the population: \( N = 4 \);
- The number of generations: \( K = 10 \);
- The probability of crossing: \( P_c = 0.6 \);
- The probability of mutation: \( P_m = 0.01 \).

**Step 3: Generation of the initial population**
We randomly generate a population of 4 noted chromosomes \( X_1, X_2, X_3 \) and \( X_4 \):
\[
X_1 = [01001], \quad X_2 = [10110], \quad X_3 = [10011] \quad \text{and} \quad X_4 = [11001].
\]

Figure 2 represents the reliability network of the configuration corresponding to the chromosome \( X_1 \).

**Step 4: Definition of objective function**
The objective function \( f \) to optimize is defined by equation 6.
\[
\begin{align*}
\text{minimize} & \quad f(X_i) = C(X_i) \\
\text{subject to} & \quad r(X_i) \geq r_{\text{min}}
\end{align*}
\]
With:
- \( r_{\text{min}} \): the minimum reliability of the structure to be optimized;
- \( C(X) \): the cost of the solution.

**Step 5: Evaluation of the reliability of each \( X_i \) chromosome in the population**
For each \( X_i \) chromosome generated, the reliability and the cost are evaluated respectively by relations 2 and 4.
So:
\[
\begin{align*}
& r(X_1) = 0.9988 \quad \text{and} \quad f(X_1) = 41.25; \\
& r(X_2) = 0.99945 \quad \text{and} \quad f(X_2) = 66.25; \\
& r(X_3) = 0.99978 \quad \text{and} \quad f(X_3) = 66.5; \\
& r(X_4) = 0.99994 \quad \text{and} \quad f(X_4) = 75.
\end{align*}
\]

**Step 6: Selection of the most suitable chromosomes**
The best chromosomes in terms of cost in descending order are: \( X_1, X_2, X_3 \) and \( X_4 \).
We select the chromosomes \( X_1, X_2 \) and \( X_3 \) for reproduction and we eliminate the chromosome \( X_4 \) because it is the worst as far as cost is considered.

**Step 7: Crossing**
We cross a couple among the selected chromosomes with a crossover rate of 0.6 to form new children. Consider the couple \( (X_1, X_2) \):
\[
X_1 = [01001] \quad \Rightarrow \quad X'_1 = [01010] \\
X_2 = [10110] \quad \Rightarrow \quad X'_2 = [10101]
\]

**Step 8: Mutation**
We do a random draw of a single chromosome gene \( X'_1, X'_2 \) and \( X_3 \); then the selected bit will be mutated with a mutation probability of 0.01. Consider the second bit of the chromosome \( X'_2 \):
\[
X'_2 = [10101] \quad \Rightarrow \quad X''_2 = [11101]
\]

**Step 9: Substitution**
We are replacing the new population with the new chromosomes. Chromosomes \( X_1 \) and \( X_4 \) will be eliminated because they are the least suitable, and the chromosome \( X_2 \) and \( X_3 \) will be kept. After all, they are the best qualified among the individuals of the population. So the new population will be made up of chromosomes \( X_1, X_2, X'_1 \) and \( X''_2 \):
\[
X'_1 = [01001], \quad X_2 = [10110], \quad X_1 = [10101] \quad \text{and} \quad X''_2 = [11101].
\]

**Step 10: Repeat steps 4 to 9**
The algorithm stops either after the reproduction of 16 generations or when we notice that the solution does not improve after a defined number of generations.

**Step 11: Optimal solutions**
The corresponding chromosome that optimize objective function is:
\[
\begin{align*}
X_a = [10001], & \quad X_b = [11000], & \quad X_c = [10100], \\
X_d = [01001], & \quad X_e = [00101], & \quad X_f = [01010]
\end{align*}
\]
- The optimum reliability and costs for each solution are:
\[
\begin{align*}
& r(X_a) = 0.998 \quad \text{and} \quad f(X_a) = 39, \\
& r(X_b) = 0.9985 \quad \text{and} \quad f(X_b) = 40.01, \\
& r(X_c) = 0.995 \quad \text{and} \quad f(X_c) = 40.5, \\
& r(X_d) = 0.9986 \quad \text{and} \quad f(X_d) = 40.25, \\
& r(X_e) = 0.996 \quad \text{and} \quad f(X_e) = 37.5, \\
& r(X_f) = 0.9967 \quad \text{and} \quad f(X_f) = 36.25, \\
& r(X_g) = 0.989 \quad \text{and} \quad f(X_g) = 32.5.
\end{align*}
\]
By considering the components selected by the genetic algorithm in the previous optimal solutions, we generate all the possible paths (connections) between the component of the machine. In solution 1 (\( X_a \) chromosome), we retain the components in parallel \( C_1 \).
and C₅; in solution 2, we retain the components C₁ and C₂ (thus defining a path); in solution 3, we retain the components C₁ and C₃ (defining a path) and from end to end until the last solution (X₉ chromosome), the last path connecting the components C₃ and C₄ is shown. From where the network of optimal reliability of the machine is given by Figure 3.

![Figure 3: Optimal network reliability of our machine](image)

By evaluating the overall reliability of the reliability network, we obtain a reliability of 0.88, higher than the minimum reliability set. Similarly, by evaluating the overall cost of the machine by applying relation 4, for the reliability network we obtain a cost of 88.75, which is much lower than the overall cost generated by the initial system, which is 103.75. Objectively, the reliability network has favored cost reduction on the one hand reliability increase on the other.

IV. Conclusion

Having completed the writing of this paper, which concerns the optimization of the reliability of a system by the genetic algorithm, it appears that the general objective has been achieved. Indeed, through the functionality of genetic algorithms, implemented on a structure with five components, we were able to reduce the cost and increase the reliability of the parallel structure. However, although the genetic algorithm is easy to implement, it might require an infinite number of iterations to the best approach of optimal solution. This would make the algorithm less robust. In perspective for this work, it would be wise to develop or implement another meta-heuristic that would not require a large number of iterations.

Data Availability

The data needed to support these results are available in the text, specifically in Table 1. Conflicts of Interest All authors declare that there are no conflicts of interest regarding the publication of this paper.

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Appealing Decisions

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

Acknowledgments

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

Declaration of funding sources

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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:

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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).

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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.

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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.

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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.

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21. **Adding unnecessary information:** Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. **Report concluded results:** Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. **Upon conclusion:** Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium through 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:
• Single section and succinct.
• An outline of the job done is always written in past tense.
• Concentrate on shortening results—limit background information to a verdict or two.
• 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:
• Explain the value (significance) of the study.
• 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.
• Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
• 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

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**BY GLOBAL JOURNALS**

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

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