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Fault Diagnosis of Lakvijaya Power Plant: A Case Study of an Anti-Rotational Pin Failure


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Abstract-Phase 1 of the Lakvijaya power plant has suffered an inherent vibration problem leading to its temporary shutdowns in 2013, 2014 and 2015. The purpose of this study is to present a hypothesis to explain causes of these vibrations, test the hypothesis and make suitable recommendations to avoid such occurrences in the future.

When the shell of one of the bearings adjacent to the intermediate pressure turbine was opened for repairs in January 2015, it was observed that the anti-rotational pin of the labyrinth seal of the bearing has been broken causing the observed unusual vibrations. There are evidences to believe that this has happened in two previous occasions as well.

The visual inspection of the fracture surface of the anti-rotation pin revealed that it has been failed from fatigue failure. Further, examination of the images of the fracture surface obtained using scanning electron microscope indicated that the fracture has originated from the outer surface of the pin and propagated to final fracture by fatigue failure. Another region of the scanning by electron microscope image showed that the pin had been subjected to heavy deflection as well.

This paper presents a hypothesis to explain how the anti-rotational pin of the labyrinth seal was failed and test the validity of the hypothesis using vibration data. Computations carried out to test the hypothesis show that the stresses inside the anti-rotational pin due to the forces exerted on it by the labyrinth seal can exceed its fatigue strength causing its failure.

Keywords—Labyrinth seal, Finite Element Analysis, 1x vibration and 2x, 3x vibrations, Cascade plot

1. INTRODUCTION

The Phase 1 of the Lakvijaya power plant was temporarily shut down in 2013, 2014 and 2015 following a vibration problem. It has been discovered during the repairs in all three occasions that at least one anti-rotational pins of the labyrinth seals of the bearing number 3 or 4(bearings of the either side intermediate pressure turbine) of the plant has been broken causing the observed high level of vibrations.
A schematic diagram of the Lakvijaya plant showing the bearings and labyrinth seals has been given in Figure 1. The turbine shaft of the Lakvijaya power plant rests on six oil pressurized bearings [1] with labyrinth seals [2] fixed at their both ends to prevent the leakage of oil. High pressure oil is continuously supplied to the bearings and labyrinth seals. The shaft rotate at rate of 3000 rpm. Vibrations of the plant is continuously monitored using a real time vibration monitoring system which acquires data from two proximity sensors[3]. Which are placed at 45° to the vertical. An accelerometer is also fixed on the top of the bearing. The proximity plots indicate relative movements of the shaft center with respect to the bearing center measured in µm.

The unusual vibration caused the tripping of the plant consisted of a high level of proximity plots with amplitudes exceeding 250 µm [4]. In addition to the proximity plots the plants electronic system is able to produce bode and cascade plots.

Further when referring to the cascade plot of the broken bearing it was found that the super synchronous [5] vibration of 300 MHz has been reported. This is the natural frequency of the bearing. This was verified by a modal test carried out by the CEB engineers.

It was hypothesized that the natural frequency (super synchronous) vibration occurrence was due to hammering of the labyrinth seal of the bearing to the bearing shell.

The main objective of the study was to provide a possible explanation for the repeated failure of the “anti-rotational pin” by studying the forces acting on the pin and analyzing the fracture surface of one of the broken pins.

Figure 1: Arrangement of the Turbine Shaft of Lakvijaya Phase-1
2. PROPOSED EXPLANATION FOR THE FAILURE OF THE ANTI-ROTATIONAL PIN

As illustrated in Figure 1 the shaft of the turbine is rested on eight bearings filled with pressurized oil and two labyrinth seals placed either side of each bearing to prevent leaking of oil to the environment. When the shaft is rotating, usually at a speed of 3000 rpm [4], the oil layers adjacent to it also rotates with the same speed and this motion is transmitted to adjacent layers finally applying a tangential thrust on the labyrinth seals. Movement of the seal due to this thrust is prevented by an anti-rotational pin which is placed in a groove and rests against the wall of the groove (Figure 2). When the seal attempts move the wall of the groove applies a thrust on the pin causing it to bend and hence the stresses on the pin get concentrated at two edges which are in contact with the wall. Periodic variation of the position of the shaft causes these stresses to fluctuate over a large range with the possibility of causing fatigue failure[6] due to the repeated variation of stresses.

3. METHODOLOGY

In order to understand the failure of the anti-rotational pin it is necessary to understand the nature of forces acting on the pin and how they arise.
There are mainly two forces acting on the labyrinth seal and the anti-rotational pin. The first is a shear load generated by the viscous action of the rotating turbine oil on labyrinth seal shaft due to the rotation of the turbine (Figure 3) while the second is the normal load in the form of pressure generated by the to and fro motion of the shaft. Since this motion is very small, the normal force generated by it is also small and can be neglected.

As the shaft moves the fluid adjacent to it also moves applying a viscous force on the labyrinth seal forcing it to rotate. However, it will be stopped by the anti-rotational pin and in the process, the anti-rotational pin will be pressed against one of the sides of the pin groove experiencing a force of large magnitude. When the shaft moves to and fro, the distance between the shaft and the seal also changes changing the velocity gradient of the oil causing the viscous force to fluctuate. This in turn causes fluctuations of the force acting on the anti-rotational pin.

As explained earlier, tangential viscous drag on the labyrinth seal originates due to the rotation of the shaft in the viscous oil. Velocity of the outer surface of the shaft can be calculated. Assuming the oil layer adjacent to the shaft rotates with the same velocity and that adjacent to the labyrinth seal is stationary, velocity gradient and the viscous force on the labyrinth seal can be calculated. It should be noted that for a given position of the centre of the shaft the gap between the surface of the shaft and inner surface of the labyrinth seal is not a constant and hence the viscous drag also varies along the seal. The following method was adopted to calculate the total viscous drag on the seal.

**Figure 4: Division of the space between the labyrinth seal and the shaft for the calculation of the viscous drag on the labyrinth seal**

In the Figure 4 the labyrinth seal is repressed by the outer circle while the inner circle represents surface of the shaft. When the centers of the both coincide the gap between the two surfaces is a constant. However, usually when the shaft is rotating, its centre moves to
and fro making this gap a variable. To calculate the total tangential viscous drag on the seal for a given position of the centre of the shaft, the gap between the two surfaces were divided into 100 segments and it was assumed over each segment the gap is a constant and hence viscous force is also a constant. Since the gap between two surfaces is very small, this assumption can be justified easily. The average gap of each segment is calculated considering the geometry of the figure using a computer routine written employing the “Mathematica” software package. Then the viscous drag on the seal along each segment was separately calculated and added together to give total viscous drag.

This tangential force makes the seal including the anti-rotational pin to move around and it will be stopped when the pin rest against the wall of the cylindrical groove (Figure 3). Now there are two forces acting on the seal; tangential viscous force and the thrust on the pin of the seal by the wall of the grove. The thrust was calculated resolving forces taking into the fact that the pin is cylindrical and the thrust on the pin is acting along the radial direction of the cylinder.

Now if we consider the pin alone it is subjected to a uniform thrust in the radial direction throughout its length. After determining the radial thrust on the pin a finite element analysis of the pin was carried out. As explained earlier initially the pin is subjected to a continuous thrust by the wall of the grove causing it to bend. The bending of the pin was modeled using the finite element method by the Lisa open source software. When the pin is bended only the edges of the pin are in contact with the wall of the grove and it was assumed contact region in each end is of 1 mm length. In fact this length could be much smaller than this value. Bending of the pin and the stress distribution under this new pressure distribution was also calculated.

4. RESULTS AND DISCUSSION

As explained earlier, tangential viscous drag on the labyrinth seal originates due to the rotation of the shaft in the viscous oil. Considering the values of the radius of the shaft and its angular speed obtained from turbine manual, velocity of the outer surface of the shaft was calculated and found to be 157.07 ms\(^{-1}\). Assuming the oil layer adjacent to the shaft rotates with the same speed and that adjacent to the labyrinth seal is stationary, velocity gradient and the viscous force on the labyrinth seal were calculated for different gaps between the shaft surface and the labyrinth seal inner surface.

The above mentioned gaps were selected based on the readings of the two proximity plots which gives the relative displacements of the centre of the shaft along two perpendicular directions (X and Y). Proximity plots give the relative displacements the shaft centre. Typical amplitudes of relative displacement of the centre of the shaft recorded by the X and Y sensors are 110 µm and 120 µm respectively. A relative displacement of 110µm on the X sensor can be produced due to the real displacement of the shaft along the X direction over several ranges of displacements. For the purpose of this calculation ranges 0-110 µm, 110-220 µm, 220-330µm were considered for the displacement along X-direction. Similarly the ranges 0-120 µm, 120-240 µm, 240-360 µm were considered along the Y direction. Table 1 and 2 give
values of the thrust applied on the edges of the pin for the three ranges along X and Y directions respectively.

Table 1: Variation of the Stress in X Direction

<table>
<thead>
<tr>
<th>Displacement of the Shaft Center in X Direction</th>
<th>Thrust on the Edges of the Pin (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 µm</td>
<td>1110</td>
</tr>
<tr>
<td>220 µm</td>
<td>1283</td>
</tr>
<tr>
<td>330 µm</td>
<td>1890</td>
</tr>
</tbody>
</table>

Table 2: Variation of the Stress in Y Direction

<table>
<thead>
<tr>
<th>Displacement of the Shaft Center in X Direction</th>
<th>Thrust on the Edges of the Pin (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 µm</td>
<td>1130</td>
</tr>
<tr>
<td>240 µm</td>
<td>1250</td>
</tr>
<tr>
<td>360 µm</td>
<td>1780</td>
</tr>
</tbody>
</table>

It is expected to use the “Von Misses” stress criterion[7] to examine the possibility of failure of the pin under the applied pressures at its ends. Therefore the “Von Misses” stress distribution of the pin was calculated under the above pressures applied on the pin at its ends using the finite element method. It was observed that the maximum “Von Misses” stress levels occur at the ends of the pin. Table-3 shows the magnitude of the maximum “Von Misses” stress occurs when the shaft center displaces 110µm, 220µm and 330 µm from the center of the labyrinth seal along the X-direction.

Table 4 shows the magnitude of maximum “Von Misses” stress occurs when the shaft center displaces 120µm, 240µm and 360 µm from the center of the labyrinth seal along the Y-direction.

Table 3: Variation of the Internal Stress with Thrust on the Pin (X direction)

<table>
<thead>
<tr>
<th>Shaft Center Displacement in X direction</th>
<th>External Pressure Applied on the Ends of the Pin (MPa)</th>
<th>Maximum “Von Misses” Stress (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 µm</td>
<td>1110</td>
<td>1332</td>
</tr>
<tr>
<td>330 µm</td>
<td>1890</td>
<td>2270</td>
</tr>
<tr>
<td>220 µm</td>
<td>1283</td>
<td>1543</td>
</tr>
</tbody>
</table>
Table 4: Variation of the Internal Stress with Thrust on the Pin (Y direction)

<table>
<thead>
<tr>
<th>Shaft Center Displacement in Y direction</th>
<th>External Pressure on the Edge of the Pin (MPa)</th>
<th>Maximum “Von Misses” Stress (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 µm</td>
<td>1130</td>
<td>1333</td>
</tr>
<tr>
<td>240 µm</td>
<td>1750</td>
<td>2080</td>
</tr>
<tr>
<td>360 µm</td>
<td>1250</td>
<td>1503</td>
</tr>
</tbody>
</table>

As can be seen from the Table 3 when the position of the shaft center varies from 220 µm and 330 µm in X direction the maximum Von Misses” stress in the pin varies between 2270 MPa and 1543 MPa. This variation exceeds the endurance limit [8] of 400 MPa of the material of the anti-rotation pin. This situation also occurs when the centre of the shaft moves from 240 µm to 360 µm in Y direction as the corresponding variation of the stresses is 577 MPa exceeding the endurance limit (Table 4). Based on these results we can suggest that it is possible for the anti-rotational pin to undergo fatigue failure as a result of variation of pressure applied at its ends originated from the viscous drag on the labyrinth seal.

The above suggestion can be further strengthen using the scanning electron microscope images of the fracture surface of the pin. Scanning electron microscope images of the fracture surface of the pin are shown in Figures 5 to 8. These images show characteristic features that can be seen in an image of a surface formed as a result of a fatigue failure. They show the presence of beach marks indicating propagation of the fatigue failure and granular surface indicating occurrence of final fracture of the pin. It can be inferred from the Figure 5 that the crack initiation has taken place at three sites labeled as 1, 2 and 3. A 48x magnification of the location-1 is shown in Figure 6. The direction of propagation cracks have been illustrated by the white arrows.

Figure 6 shows continuation of the fatigue failure initiated at location -1. The white arrows in Figure 6 shows the propagation of the crack in white arrows. Figure 7 also shows the location-2 where the crack initiated. Figure 8 shows the beach marks initiated near the location-3 leading to the final fracture resulting a granular surface. Therefore it can be concluded based on the electron microscope images that the pin has been failed due to the “fatigue failure”.

Considering the calculations presented in relation to the “Von Misses” stresses subjected the pin and electron microscope images it is concluded that the anti-rotational pin has undergone fatigue failure as a result of variation of pressure applied at its ends originated from the viscous drag on the labyrinth seal as hypothesized in this study.
Figure 5: Scanning Electron Microscope Image of the surface of the broken Anti-Rotation Pin showing identified Locations (1, 2 and 3) for further study.

Figure 6: Scanning Electron Microscope Image of the surface of the Pin at Location-1.
Figure 7: Scanning Electron Microscope Image of the surface of the Pin at Location-1 (cont.)

Figure 8: Scanning Electron Microscopic Image of the surface of the Pin at Locations 2 and 3
CONCLUSION

A possible reason for breaking down of the anti-rotational can be explained as follows. When the labyrinth seal tries to rotate, it exerts a pressure on the anti-rotational pin which attempts to stop this rotation. This pressure causes the pin to deform. Inspection of proximity plots revealed that the relative position of the shaft center undergoes periodic displacements causing the gap between labyrinth seal and the shaft periphery to vary. This in turn changes the viscous force acting on labyrinth seal and hence the pressure acting on the anti-rotational pin.

Therefore it can be concluded that the “anti-rotational” pin has subjected to the “Fatigue Failure” and the pin’s diameter is not sufficient to the stress variation as the shaft position varies.

REFERENCES


Smart Bliss Board System for Multiple Disabilities

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Abstract – This paper presents a communication mechanism for multiple disabled in the world (such as blindness, deaf, mental retardation, vocal disabled etc.). They have very few mechanisms to learn and communicate (Braille system, Sign language etc.). This work focuses on the category of the multiple disabled named “Cerebral Palsy”. Cerebral palsy is a disorder with movement, difficulties with thinking, learning and feeling. Most people of cerebral palsy are suffering in inability to read, write or speech. Therefore, they are unable to express their ideas naturally to others. On the other hand, they are unable to perceive others ideas as well. These communication barriers caused them to their teaching and learning. The Bliss symbolic language board is a concept for a learning method for the Cerebral Palsy disabled.

At present, the Bliss symbols are printed on hard board. When using this printed Bliss board in the classroom, the teacher/tutor must concentrate each multiple disabled child separately to understand his/her expression using Bliss symbols. This is the main problem in their teaching and learning of multiple disabled children/adults. Basically, they use a head attached stick for touching each bliss symbols on a Bliss board. This is a difficult task for them to use this Bliss board and also multiple disabled children/adults are unable to use new technology such as send emails, chatting etc. due to their disabilities. Literature survey found that the other similar systems for Bliss symbolic language learning are also difficult for use by physically challenging persons because they are unable to access modern devices such as a computer or mobile phones directly. But in this research mainly consider about the accessibility of modern technology.

Proposed Smart Bliss Board system is running on a desktop application with a head movement tracking device to select appropriate Bliss symbol automatically. The proposed system is very interactive than the existing printed Bliss symbolic board because the users (physically challenging children or teachers) can select each Bliss symbol by using moving cursor. In this project, developed an electronic wearable device for controlling the cursor movement on a computer screen using a head attached accelerometer device. After pointing or touching Bliss symbols, then the device automatically lookup and convert to the English language text and voice of the pointed Bliss symbol and then the users can send the message to the teachers. The teachers can use a desktop PC or a tablet PC to response the respective message of the users. The results showed that the significant improvement of the communication of the physically challenging children with the proposed technology over the traditional printed Bliss board. When using the proposed system, teachers do not need to interact with Bliss symbolic words. They can easily type required messages using the English language, and then it will automatically convert to the Bliss symbolic language sentence and send back to the users. This Bliss symbolic language application is designed for simplifying the reading, writing for the people with cognitive, language, and learning disabilities or literacy problems. And also this application can be used internationally among many users and teachers those who do not speak the same spoken language.

Keywords: Bliss symbolic language, Cerebral Palsy, Multiple disability, Wearable electronic device, Head movement tracking
1. INTRODUCTION

1.1 Project Introduction

There is a significant amount of multiple disabled children and adults in Sri Lanka. According to the reference report (Gunasinghe, 2004), there were 4320 multiple disabled in Sri Lanka in 2003. Moreover, it can be seen more children with physical disabilities (Cerebral Palsy) in homes for disabled such as Preethipura infants' home (Wattala), Asokapura Farm and Cotagala School (Kadugannawa) and Anandapura Farm (Katana) there are more physically challenging (Cerebral Palsy) children. And also there are some physically challenging army soldiers in Ragama army hospital and Bellanwila army hospital in Sri Lanka, due to bomb blasts at the battle field. Some children are suffering from multiple disabilities such as Cerebral Palsy. And some children are suffering from multiply disabled after a vital shock of their lives like bomb blast or losing their very hopeful dreams.

Most of the special education teaching schools are following conductive traditional education system. Conductive education is a comprehensive method of learning by which individuals with neurological and mobility impairment learn to specifically and consciously perform actions that children without such impairment learn through normal life experiences. Those schools try to teach multiple disabled children using different techniques such as a book or poster with pictures that show things the child might want, or an alphabet board they can use to spell out their message, teaching with the Bliss symbolic board. But there is not achieving satisfaction level based on the interview (Deldeniya, 2014) and noted that some methods (such as using the alphabet board and express their message) hard to follow-up such children.

According to the interview (Deldeniya, 2014), the present successful learning and teaching method for multiple disabled (especially Cerebral Palsy) is a Bliss symbolic board. But that also has difficulties when using it with physically challenging people. The usage of the Bliss board system is less in Sri Lanka but all over the world currently use this technique to teach them using their own language integrations.

Therefore, the main aim of this project is to develop a method of teaching, learning and communicating with multiple disabled children using new technology and Bliss symbolic language and implement a mechanism, to express their message, feelings and ideas to other physically challenging people or normal not impaired people using the Bliss symbolic language to the English language and the English language to Bliss symbolic language vice versa using voice and text.

1.2 Issues in the Existing Systems

There are more ways to educate normal children, such as reading, writing, listening, and watching. Based on these four activities, they have various learning resources to refer such as books, radio, television, internet, normal observing environment, telephone, computers etc. However, there are some amounts of multiple disabilities (such as some are blindness, deaf, mental retardation, vocal disabled etc.), they have very few ways to learn (Braille system, Sign language etc.).

The Bliss symbolic language board can be used as learning tool for multiple disabled children (Bliss Communication International, 2014). But at present, this Bliss symbols
printed on a board, therefore when using it following problems may face by physically
challenging users and tutors.

- In a classroom teacher/tutor must concentrate each multiple disabled child
  separately to understand his/her expression using printed Bliss board.
- Multiple disabled children/adults currently use the Bliss symbolic board using the
  head attached stick by touching each symbols on the printed board (Figure 1). This is
  a difficult task for them to express their view to the others.

![Figure 1: Current usage of the printed bliss board by physically challenging child](image)

- Using this existing Bliss board, the physically challenging persons are unable to
  communicate their feeling or message to others directly.
- Multiple disabled children/adults unable to use new technology such as send
  emails, chatting etc. due to their disabilities.

1.3 Aim & Objectives

1.3.1 Aim

The aim of this project is to develop an interactive smart Bliss board system for multiple
disabilities.

1.3.2 Objectives

- Identify the learning difficulties of children with multiple disabilities.
- Develop a wearable electronic headband unit to capture the head movement and
  locate a particular Bliss symbol in a Bliss Board.
- Develop a desktop application for Bliss symbolic language.
- Implement a mechanism to communicate Bliss symbolic messages among the
  users as individual or group.

1.4 Project overview

The Smart Bliss Board system contains Windows operating system based application.
This system is very interactive than the current printed Bliss symbolic board. Because
when using this Bliss board system, the users (physically challenging children or teacher)
can select each Bliss symbol by moving the cursor on to the required symbols or touching the symbols. There is an electronic hardware device for controlling the cursor movements on the computer screen using the user’s head attached accelerometer device. After pointing or touching symbols using this electronic hardware device, then it will automatically convert to the respective English language text and voice, and then the users can send their messages to the teacher’s computer.

In Windows based application teacher replies his/her answer as a symbolic message to the Bliss board user. When using this system, the teachers no need to interact with the Bliss symbolic words, they can type required message using English, and then it will automatically convert to the Bliss symbolic language sentence.

If there is more than one user in the classroom, each message list and displays in the desktop application, and then the teacher can reply to each message separately or as a group.

And also anyone who does not know about Bliss language can communicate with the physically challenging persons through this application. They can learn and express their ideas via Bliss symbolic language to physically challenging children. Therefore, this system can use as a Bliss symbolic language learning tool for physically challenging persons or the other persons.

2. LITERATURE SURVEY

2.1 Literature survey on Bliss symbolic language system

2.1.1 Bliss Symbol Communication Board

Bliss Symbol Communication Board has been used internationally for promoting communication among non-verbal adults and children, who cannot otherwise, read or spell. The Bliss symbols were selected to convey general concepts that could be combined together to form words. Bliss symbols are easily recognizable idiographic symbols and some of them are also pictographs. Bliss symbols have been used world-wide working with different clinical populations and have been found to be very effective in promoting communication. The Bliss symbol communication Board reproduced in Figure 2 contains five hundred seventeen (517) of symbols. The English word for each symbol is printed underneath for the convenience of the user (Bliss Communication International, 2014)(Bliss Communication UK, 2010).

Color index of the board

- White – Normal day today usage words
- Light blue – Person
- Brown / Pink – Tense and Verbs
- Green – Feelings and Adjectives
- Yellow – Nouns
Figure 2: Bliss Symbolic Board
2.1.2 Why Bliss?

The Bliss symbolic system has several features which make it a preferred means of communication for non-speaking persons, for persons with limited literacy skills, and for persons who are ready and eager to use Bliss to communicate with persons whatever their language background may be (Bliss Communication International, 2014).

2.1.3 Who uses Bliss?

The system is used with persons with severe speech and physical impairments (SSPI) in over 33 countries and Bliss symbol materials have been translated into more than 15 languages. Mostly Bliss symbolic language system is used to teach to multiple disabled (handicapped) children who are suffering from Cerebral Palsy. And special thing is, to learn this Bliss symbolic language users (physically challenging person) must be intelligent to understand. Also this Bliss symbolic language can be used by anyone who doesn’t know to speak country related language (Like Chinese, Japanese, Arabic, Sinhala, etc.) to express his idea/ message to other (Bliss Communication International, 2014).

2.1.4 How Bliss Works?

Bliss symbolic makes use of core symbols (Bliss-characters), many of which are intuitive and pictographic. They can be arranged to produce Bliss-words that can represent complex and abstract, yet easy-to-understand meanings. There are around 100 basic symbols, which can be combined endlessly to form new concepts. Nouns can be changed into verbs or adjectives with the addition of an indicator, and there are also simple past and future tenses. Bliss has simple, elegant, logically based rules that make it ideal as an on-phonetically based language. (Bliss Communication International, 2014)

- Bliss-character (Wikipedia, 2014)
  
  Figure 3.1 shows an individual graphic symbol of Bliss language (ideograph).

  ![Bliss characters](image)

  **Figure 3.1: Bliss characters**

- Bliss-word
  
  Represents a concept or meaning and is spelled using a sequence of one or more Bliss-characters. (Figure 3.2)

  ![Bliss words](image)

  **Figure 3.2: Bliss words**
Indicators

Characters used to show the part of speech of a symbol. (Figure 3.3)

\[ \times \quad \wedge \quad \vee \quad ) \quad ( \]

**Figure 3.3: Bliss indicators symbols**

Now you can say, (same as Sinhala language can express idea) (Figure 3.4)

![Bliss sentence expression](image)

**Figure 3.4: Bliss sentence expression**

### 2.2 Literature survey on similar systems

Literature survey found that the other similar systems for Bliss symbolic language learning are also difficult for use by physically challenging persons because they unable to access modern devices such as a computer or mobile phones directly, due to their disabilities. But in this research mainly consider about the accessibility of modern technology (Sensorysoftware, 2001).

### Table 1- Comparison of similar Bliss symbolic systems with the proposed system

<table>
<thead>
<tr>
<th>Bliss symbolic system name</th>
<th>Can use disabled</th>
<th>Separate device</th>
<th>Software/Web</th>
<th>Required an internet connection</th>
<th>Email Facility</th>
<th>Text Output</th>
<th>Voice Output</th>
<th>Cursor cont. by Face movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bliss board (printed on paper)</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bliss Online!</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The Grid 2</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>Blissvox</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>Proposed System</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
3. METHODOLOGY

The proposed methodology is shown in the Figure 4. There are mainly two type of devices which are running on Windows operating system. A device for the physically challenging person and a device for the teacher or any normal user who wish to communicate with the physically challenging person as follows.

3.1 Approached of the Project

The device which is used by the physically challenging person (left hand side of the Figure 4) has a connection to the wearable electronic headband unit which can move the mouse cursor position in the developed software application. The other device is a normal device which is used by the teacher and has a separate software application. These devices connect via Wi-Fi or the internet to communicate with each other.

3.2 Features of the System

1. Physically challenging user can select Bliss symbols of the smart Bliss board by touching or pointing mouse cursor using headband unit.
2. Display the related Bliss symbols according to the user preference and translates to the voice output.
3. Any users can send their messages to the others via internet using smart software application.
4. After receiving the message to the teacher’s or the normal user’s device, then they can view the received massages and reply in English text.
5. Enriched with English text to Bliss symbolic and Bliss symbolic to English text language generator/converter of the smart software application to facilitate the communication between each other.
3.3 Advantages of proposed system

1. This Bliss system can access physically disabled and children with communication problems without any difficulty.
2. Teacher or tutor especially no needs to concentrate about each physically challenging child as existing method when using a developed Bliss system.
3. Teacher can get multiple message same time from each individual student separately.
4. More interactive, efficient than existing printed Bliss board.
5. Physically challenging people can use messages and email facility.
6. Anyone can learn about Bliss symbolic language through the smart Bliss board system.

4. DETAILED EXPLANATION

4.1 Components integration diagram of the system

![Component integration diagram of the system](image)

Figure 5: Component integration diagram of the system

Figure 5 shows the integration among each component of the proposed system such as Wearable mouse cursor controlling device, mouse protocol circuit unit and the ‘Bliss Smart’ application on the desktop PC.
Figure 6 shows the flowchart for the main control logic of the proposed system. There are two modes in the developed system. They are User mode and the Tutor mode. Based on the different mode selection, the developed software can be configured to use as a user device or a teacher/tutor device.

### 4.1 Flow Chart of the Operation of the System

[Flow chart image]

Figure 6: Flow diagram for smart Bliss board system
5. IMPLEMENTATION

5.1 Wearable Mouse Cursor Controlling Device Unit

Figure 7: Wearable mouse cursor controlling device unit

1. Headband with accelerometer (ADXL335)
2. Microcontroller unit
3. USB plug
4. Right Mouse Button
5. Left Mouse Button

Figure 8: Microcontroller unit

1. MSP430 Launch-pad with MSP430G 2553 microcontroller
2. Mouse protocol circuit
3. PS/2 to USB converter circuit
4. Wire for mouse left, right button
5. Wire for USB port
6. Wire for accelerometer
The above images (Figure 7,8) describe the hardware integration with components. MSP430 launch pad (Texas Instruments, 2010) provides the MSP430 G2553 microcontroller to control all of functions of the system (Texas Instruments, 2014). ADXL335 accelerometer (Goodrich, 2014) connects to the MSP430 launch pad microcontroller. Accelerometer sends the signals of acceleration (movement on x, y, z axis) of each axis, then microcontroller identify those signals and convert it to mouse protocol signal using the programming language (Energia, 2010). That signal send to the mouse protocol circuit and it generate the signal for mouse cursor movement of the computer screen. In above hardware integration include a PS/2 to USB converter circuits (Chapweske, 2003) to enable USB connecting facility with computer.

5.2 Windows phone application GUI

Figure 9.1 shows the home screen of the “Bliss Smart” Windows based app. It includes student sign in, tutor sign in and guest sign in links and it also include link to tutor/student sign-up page. Rest of the page displays Bliss Smart user guide and information about Bliss language.

Figure 9.1: Login screen for students and tutors

Figure 9.2 shows a tutor sign up on screen. Tutors can register by providing required details of the interface. And also in this page provide a link to student sign up page. Tutors can register students via this link. In this page shows all are registered tutors in the class room.

Figure 9.2: Tutor sign up screen
Figure 9.3 shows the student register. The function can accessible for tutors via their sign up page, because physically challenging users unable to enter their details by own. Therefore, tutors must input student details to the app via this interface, this page also shows all already registered students of the class room.

**Figure 9.3: Student sign up screen (Sign up process must do by tutor)**

Figure 9.4 shows the Bliss board system for students. Screen shows standard bliss board and chat function with friends or tutors of the class room. When selecting bliss symbol from the bliss board, those symbols displayed on user selected symbol field and it will convert to text.

**Figure 9.4: Bliss board for students**

In this screen facility to on/off chat service and chat with selected friend or tutor of the class room. Physically challenging user need to narrate the selected bliss symbols meaning in English, they can narrate it by clicking on the speaker button.

Figure 9.5 shows the Bliss board system for guest. Screen shows standard bliss board and only few features such as Bliss symbol to text service and narrates service. Because this interface provides users who are not register in this system.

**Figure 9.5: Bliss board for guests**
Figure 9.6 shows the tutor interface of the “Bliss Smart” windows based app. This screen provides only who are logging using correct credential for tutor login. In this interface, shows messages of students sent to him/her. And tutor provide a bliss writer interface, on that interface tutor can type his/her message in English and then that English words converted to the Bliss symbols. Then tutor can send the message to selected student or selected group of students. If user wants to use Bliss board, tutor can visit to that page also.

6. TEST EVALUATION

6.1 Test cases of the project

- Head movement tracking convert to mouse cursor feature.
- Head movement tracking device left & right buttons to check the working condition.
- Tutor & Student signup on the Smart Bliss windows application
- Login Function of Student & Tutor
- Display selected bliss symbols, when click on any symbol of the bliss board.
- Narrate selected word symbols, when click on the speaker button.
- Chat service with other users who logged into the system.
- Bliss writing function of the tutor page.

When testing the developed smart Bliss board system, I mainly considered about the percentage of the achievement of the objectives of the project which was defined in the Introduction Section. After identifying the learning and communication difficulties of multiple physically challenging students, I developed a new technological solution for overcome those difficulties. First, I developed a head movement tracking mechanism and then it tested on computer and finalized. Then, I started developing desktop application for Bliss symbolic language use standalone without communication facility. After clarifying the successful working condition, I started to develop a mechanism to communicate Bliss symbolic messages among desktop application users. After doing those successful steps it applied on actual environment at the Prithipura infant home – Wattala as shown in the Figure 10 (Prithipura Communities, 2008).
7. CONCLUSION

This smart Bliss board system is designed for the physically challenging people who are having communication problems. This design helps to access new computer technology via head movement tracking device with special computer application. Head movement tracking device to capture the head movement and it converts to mouse cursor movement on the computer screen. This system will help physically challenging people to express their ideas and messages to others. After identify and complete the first objective, the second objective of the project could successfully achieve using an accelerometer sensor device with MSP430G2553 microcontroller. This device has great advantages over the other similar systems. Also, this head movement tracking device can be used to control other applicable applications on the computer, such as playing some games and educational applications.

Developing a desktop application for Bliss symbolic language was the third main objective of this project. To achieve this objective, I used Windows based operating system (Windows 8) platform to develop this desktop application. This application directly helps learning & teaching Bliss symbolic language to physically challenging persons. And also, it will help those who want to express an idea or communicate with the unknown language speaker. It could successfully complete with project mentioned features and facilities.

The final objective of the project was an implementation a mechanism to communicate Bliss symbolic messages among desktop application users as individual or group. This communication mechanism successfully runs in real time via the Internet. This application facilitates many of this ‘Smart Bliss’ application users for communication in real time.
In future developments, a web based Bliss symbol application will benefit the users who have a computer and an Internet facility. This project is not only for those who have multiple physical challenges but this can also be used by anyone who does not know how to communicate with unknown language using human in other country in the world.

8. ACKNOWLEDGEMENT

I would thanks to Dr. T.D.T.L. Danapala, Head of the Department and Dr. K.A.C. Alwis, Senior Lecturer in the Department of Special Needs Education, Faculty of Education of the Open University of Sri Lanka, and Ms. W.N. Deldeniya, a retired lecturer of National Institute of Education (NIE - Maharagama). I also specially thank following great persons in the Prithipura infant s home – Wattala who helped me to do the project successfully.

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✓ Mr. Widura - Office assistant (Prithipura Infants Home - Wattala).
✓ Mr. Palinda - Cerebral Palsy suffering student (Prithipura Infants Home - Wattala).

Also, I would like to pay my great gratitude to my parents for being my mentors and advisors. They not only encouraged me, but also gave me the helping hand to finish this project.

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Illustrating the Possibility of Modelling the Gravity Anomalies in Terms of Bodies Having Density Vary with Depth

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Abstract - The main focus of this study is to test the hypothesis that the Backus-Gilbert inversion method can be used to model gravity anomalies in terms of bodies having density vary with depth in terms of local averages using constructing averaging kernels and applying it for a special case of a geological fault.

Keywords: Backus and Gilbert method, averaging kernels

INTRODUCTION

Backus and Gilbert (1967, 1968 and 1970) described a mathematically rigorous approach of solving the inverse problem in geophysics for the under-determined case. This inversion method is based on a mathematical abstraction called an “Earth Model”. An ordered n-tuple of functions of positions that is sufficient to define an idealized model is known as an “n-dimensional Earth model”. Such a model can be considered as a point in an infinite dimensional linear space of all conceivable Earth models. In this method, a model that satisfies a set of observations is created by minimizing the distance between an initial model and the real Earth model in the parameter space, subject to the constraints imposed by observations.

Green (1975) described how the Backus and Gilbert method can be used to model gravity anomalies in terms of constant density bodies. This paper investigates the possibility of using this method to model gravity anomalies in terms of bodies with increasing density applying it for a special case of a geological fault.

A normal geological fault is formed as a result of breaking of a large Earth structure into two blocks and subsiding one of them relative to the other. The void created by the subsidence of the block will normally be filled with sediments and density contrast between the sediments (ρₛ) and the other block that did not subside (ρᵥ) produces a gravity anomaly. It is possible to
model a normal fault by merely modelling the region of sedimentary rocks as a semi-infinite slab with a density contrast of \((\rho_s - \rho_c)\). In such a body, the sediments in the lower part of the sequence are consolidated and have higher densities while those on the upper part are not consolidated and therefore have lower densities. It will be shown here that it is possible to recover this vertical density variation using the Backus and Gilbert method.

This study is further extended to test the hypothesis that the Backus-Gilbert inversion method can be used to model gravity anomalies in terms of bodies having density vary with depth in terms of local averages using constructing averaging kernels.

As explained by Menke (1984) it is necessary to have an infinite amount of information in the form of observations to predict the continuous variation of a certain physical property of the Earth such as density or electrical conductivity with depth. In real world studies only a limited amount of data or observations are available. In such instances instead of predicting the continuous variation of the physical quantity with depth it is possible to predict how the local average of the physical quantity over a certain interval around a given point vary with depth using the Backus and Gilbert method. The theory related to determination of local averages by constructing averaging kernels has been explained under Averaging kernel sub heading.

**METHODOLOGY**

The feasibility of modelling a normal geological fault with increasing densities with depth using the Backus and Gilbert method was examined by inverting the artificially simulated gravity anomaly data due to a hypothetical geological fault of known dimensions and a known density distribution using this method and then comparing the results obtained with the relevant features of the hypothetical fault.

Figure 1 shows the hypothetical fault with density that increases with depth and the gravity anomaly it produces used for the numerical experiment. First the anomaly was modelled in terms of a body of constant density using the version of the Backus and Gilbert method for gravity modelling presented by Green (1975) after suitably modifying it for modelling of a fault using the following steps.

1. Divide the initial trial 2D of rectangular cross sectional shape into a number of semi-infinite slabs.

2. Determine density contrast of each slab using the Backus and Gilbert method together with the singular value decomposition method.

3. Neglect the semi-infinite slabs having positive density values or density values close to zero by taking their thickness equal to zero.

4. Assign a particular value for the density of remaining semi-infinite slabs and calculate the gravity anomaly due to the new body and compare it with the “Observed anomaly”. If the agreement is not acceptable, then repeat steps 2 and 3 above until a suitable agreement is obtained.
Figure 1: The shape of the body (collection of 2D semi-infinite slabs) and the gravity anomaly it produces.

Figure 2: The shape of the initial trial body of the iteration process.
Figure 3: Gravity model obtained after the first iteration and the gravity anomaly it produces (blue dashed line).

Figure 4: Gravity model obtained after the fifth iteration and the gravity anomaly it produces (blue dashed line).
Gravity anomaly due to a two dimensional model fault (Figure 1) has been computed using the “Wolfram Mathematica 7”. The model obtained by the use of the above method consisted of five consecutive slabs of equal density contrast of -0.3 g/cm³. Then to model a body with increasing densities, each slab of the model was divided into five horizontal strips so that the whole model is now divided into 25 strips. It is well known that in shallow depths, density of sediments increases linearly with depth. A density value for each strip was assigned a value assuming a linear increase of density with depth. Then using the Backus and Gilbert method, an attempt has been made to determine a density distribution for strips that is closest to the assumed values and also satisfies the observations.

For the test example, depth to the basement is considered as 3.5 km while its density contrast values are -0.3, -0.28, -0.26, -0.24, -0.22 g/cm³. Gravity anomaly was calculated over a range of 50 km at intervals of 1km. The averaging kernels of each layer were calculated using the “Wolfram Mathematica 7”.

Density values obtained for the each strip of each slab and the constant density value used for the each slab for the hypothetical fault are given in the Table 1 and also illustrated in Figure 5. As can be seen from this Table 1, densities of the set of first five strips are very closely equal to the density of the first slab of the hypothetical fault. Similarly the densities of 2nd, 3rd, 4th and 5th sets of five strips have densities approximately equal to the densities of 2nd, 3rd, 4th and 5th slabs of the hypothetical fault.

**Singular value decomposition**

The Singular value decomposition (SVD) is one of the most versatile and useful tool in Linear Algebra. Linear algebra is the study of linear operators which map vectors between two vector spaces. Matrices are convenient representations of linear operators.

The purpose of singular value decomposition is to reduce a dataset containing a large number of values to a dataset containing significantly fewer values, but which still contains a large fraction of the variability present in the original data. Often in the atmospheric and geophysical sciences, data will exhibit large spatial correlations. SVD analysis results in a more compact representation of these correlations. This technique is a generalization of the eigenvector decomposition of matrices to non-square matrices and is explained below.

In the SVD method a data kernel, an $N \times M$ matrix $G$ is factored into $G = U S V^T$ so that,

$U$ is an $N \times N$ orthogonal matrix with columns that are unit basis vectors spanning the data space, $R^N$.

$V$ is an $M \times M$ orthogonal matrix with columns that are basis vectors spanning the model space, $R^M$.

$S$ is an $N \times M$ diagonal matrix with diagonal elements called singular values.

The singular values along the diagonal of $S$ are customarily arranged in decreasing size, $s_1 \geq s_2 \geq s_3 \geq \cdots \geq s_{\min(N,M)} \geq 0$. Note that some of the singular values may be zero. If only the first $p$ singular values are nonzero, we can partition $S$ as

$$S = \begin{bmatrix} S_p & 0 \\ 0 & 0 \end{bmatrix}$$
where \( S_p \) is a \( p \times p \) diagonal matrix composed of the positive singular values. Expanding the SVD representation of \( G \) in terms of the columns of \( U \) and \( V \) gives

\[
G = [u_1, u_2, u_3, ..., u_N] \begin{bmatrix} S_p & 0 \\ 0 & 0 \end{bmatrix} [v_1, v_2, v_3, ..., v_M]^T
\]

\[
G = [U_p \  U_0] \begin{bmatrix} S_p & 0 \\ 0 & 0 \end{bmatrix} [V_p \  V_0]^T
\]  

(1)

where \( U_p \) denotes the first \( p \) columns of \( U \), \( U_0 \) denotes the last \( N - p \) columns of \( U \), \( V_p \) denotes the first \( p \) columns of \( V \), and \( V_0 \) denotes the last \( M - p \) columns of \( V \). Because the last \( N - p \) columns of \( U \) and the last \( M - p \) columns of \( V \) in [1] are multiplied by zeros in \( S \), we can simplify the SVD of \( G \) into its compact form \( G = U_p S_p V_p^T \). Further by using the SVD, generalized inverse of \( G \) \((G^{-\theta})\) can be obtained as;

\[
G^{-\theta} = V_p S_p^{-1} U_p^T
\]  

(2)

**Averaging Kernel**

Backus and Gilbert (1968, 1970) have developed a powerful technique for making reliable generalizations from an incomplete data set. Only a simplified version of their technique will be needed here. Suppose we wish to estimate some function of radius in the Earth \( m(r) \) from a set of observations \( g_i \) which are functionally dependent, in a known way, on \( m(r) \). For a spherically layered earth, we may write

\[
\sum_{j=1}^{M} G_{i\ j} \ m_j = g_i \quad i = 1, 2, ..., N
\]  

(3)

where

- \( G_{i\ j} \) are some known coefficients,
- \( g_i \) are the data and
- \( m_j \) are the values of the unknown in the \( M \) concentric layers.

If \( M > N \), the system of equations [3] is underdetermined, and if any solution exists, there is an infinite number of solutions will exist.

Let us sum both sides of [3] over a set of coefficients \( a_i^k \)

\[
\sum_{i=1}^{N} \sum_{j=1}^{M} a_i^k \ G_{i\ j} \ m_j = \sum_{i=1}^{N} g_i \ a_i^k
\]  

(4)

Supposing that \( a_i^k \) can be found such that

\[
 A_j^k = \sum_{i=1}^{N} a_i^k \ G_{i\ j}
\]  

(5)

is about 1 for \( j = k \), and near zero otherwise. Then the right side of equation [4] will have physical meaning as a “local average” of the property \( m(r) \) near the \( k^{th} \) layer. We may pick a separate set of coefficients \( a_i \) for each layer \( k \) which we wish to investigate.

We then have

\[
 \hat{m}_k = \sum_{i=1}^{N} a_i^k \ g_i
\]  

(6)
as the local average of $m(r)$ near layer $k$. Note that equation [4] will be true for any set $a_i^k$ but will have its useful physical meaning only if $a_i^k$ are chosen such that equation [4] has the “delta-like” property advertized.

Table 1: The calculated density values of each semi-infinite slab

<table>
<thead>
<tr>
<th></th>
<th>1st Slab (g/cm³)</th>
<th>2nd Slab (g/cm³)</th>
<th>3rd Slab (g/cm³)</th>
<th>4th Slab (g/cm³)</th>
<th>5th Slab (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed</td>
<td>-0.3</td>
<td>-0.28</td>
<td>-0.26</td>
<td>-0.24</td>
<td>0.22</td>
</tr>
<tr>
<td>1st Strip</td>
<td>-0.291</td>
<td>-0.277</td>
<td>-0.262</td>
<td>-0.238</td>
<td>-0.219</td>
</tr>
<tr>
<td>2nd Strip</td>
<td>-0.289</td>
<td>-0.275</td>
<td>-0.260</td>
<td>-0.237</td>
<td>-0.218</td>
</tr>
<tr>
<td>3rd Strip</td>
<td>-0.288</td>
<td>-0.268</td>
<td>-0.247</td>
<td>-0.231</td>
<td>-0.218</td>
</tr>
<tr>
<td>4th Strip</td>
<td>-0.278</td>
<td>-0.266</td>
<td>-0.248</td>
<td>-0.230</td>
<td>-0.220</td>
</tr>
<tr>
<td>5th Strip</td>
<td>-0.277</td>
<td>-0.262</td>
<td>-0.238</td>
<td>-0.230</td>
<td>-0.212</td>
</tr>
</tbody>
</table>

Figure 5: The density contrast values assumed for 5 slabs of the hypothetical model (Straight line) and those calculated for the 25 layers using the Backus and Gilbert method (zigzag line)
DISCUSSION

Even though in most geophysical studies it is assumed that subsurface structures causing gravity anomalies have constant densities, in reality they have densities that increases with depth. Modelling of gravity anomalies using the powerful Backus and Gilbert method was so far limited to modelling of bodies with constant densities. This study illustrates that the Backus and Gilbert method can be extended to model gravity anomalies due to bodies with increasing density. However, the present study is only illustrates the possibility of modelling of gravity anomalies due to a geological fault. The method can be extended for other geological structures such as sedimentary basins and igneous intrusions with appropriate modifications.

REFERENCES


Evaluation of Microwave Assisted Alkaline Pretreatment for Extraction of Cellulose from Selected Lignocellulosic Materials

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Abstract:

The objective of the present study is to evaluate the performance of the microwave assisted pretreatment method by subjecting five selected biomasses; Corn leaves, Corn Husks, Bagasse, Guinea grass and Sugar cane leaves, to obtain the maximum cellulose percentages with optimum pretreatment concentration and minimum exposure time on selected range. This method was performed by using a domestic microwave oven. Different concentrations of three solutions; NaOH - 1.25 mol/L, 2.5 mol/L and 5 mol/L were used as pretreatment solutions. Total of 25 g of selected biomass with 250 ml of pretreatment solution was added in a 500 ml beaker and irradiated under microwave power of 170 W for 15 minutes, 30 minutes and 45 minutes. Forty five treatments consisted of combinations of five biomasses, three NaOH solutions and three exposure time for irradiation. Percentages of weight losses of pretreated fibers were measured. In addition, Percentages of cellulose of treated fibers were evaluated using chlorination method. Data was analyzed by using Minitab 14 version. Additionally, pretreated fibers with the highest percentage of cellulose obtained after evaluation of samples were analyzed using Fourier Transform Infra-Red Spectrometry (FTIR) to confirm extracted fibers were cellulose. Analysis results indicated that biomass, NaOH concentration, time and (Biomass × NaOH concentration) were significant for percentage weight loss. Except for time and (NaOH concentration × Time), other factors were significant for percentage cellulose extracted (P <0.05). According to the results of main and interaction effects graphs of percentage of cellulose, all pretreated fibers comprised 65% - 85% of cellulose from pretreatment comprising 5 mol/L NaOH and 15 minutes of 170W microwave dose. FTIR analysis of extracted cellulose fibers from 5 mol/L NaOH and 15 minute treatment confirmed that extracted fibers were cellulose. Best condition for microwave alkaline pretreatment for a selected biomasses was found to be 5 mol/L NaOH and 15 minutes of 170W microwave dose.

Keywords: Microwave Assisted Pretreatment, Lignocellulosic materials, Cellulose

1. INTRODUCTION

Lignocellulosic materials are the most abundant biopolymer available in nature showing potential for ethanol production including agricultural residues such as corn straw, wheat straw bagasse, sugar cane leaves and guinea grass which are widely available in Sri Lanka. Using these, several researches have been initiated for production of activated carbon, bio ethanol and gasification by extraction of cellulose. Lignocellulosic plant materials are a matrix of hemicelluloses wrapped around long chains of cellulose encased in lignin (figure 1). Compositions of cellulose, hemicellulose and lignin are different from each other. Table 1
indicates the different percentages of chemical composition of mostly available lignocellulosic material in Sri Lanka. This paper discusses extraction of cellulose from selected lignocellulosic materials with an effective method. After extraction cellulose fibers were processed to produce cellulose based biodegradable Super Absorbent Polymers for different agricultural practices in Sri Lanka. Super Absorbent Polymers (SAPs) are mostly used to retain available water in the soil which enables the plants to survive longer under water stress and enhanced water holding capacity of the plant (Barbucci et al., 2000).

Pretreatment methods are necessary to remove or alter the lignin from lignocellulosic materials (figure 1). An effective pretreatment of these lignocellulosic materials is needed to liberate the cellulose from the lignin seal and at the same time to reduce the lignin content, to reduce cellulose crystallinity and to increase cellulose porosity (Zhao et al., 2006 and Zhao et al., 2008). Pretreatment methods are suffered from relatively low sugar yields, severe reaction conditions, large capital investment, high processing costs and great investment risks (Alvira et al., 2010, Kumar et al., 2009). Acid pretreatment is able to hydrolyze the cellulose and hemicelluloses but capital cost is high because of the formation of inhibitors and equipment corrosion problems (Wyman, 1996). Oxidative pretreatment usually results in losses of cellulose and hemicellulose due to the fact that all oxidants used are non-selective (Hendriks et al., 2009). Pretreatment with organic solvents is too expensive to be employed for biomass though pure lignin could be obtained as a byproduct (Zhao et al., 2009). Biological pretreatment which commonly involves the use of the white rot fungus to degrade lignocelluloses requires low energy input, low capital cost and mild environmental conditions. However, it is otherwise unattractive at industrial scale because of slow conversion rates (Aita et al., 2010). Extensive reviews on pretreatment process methods and the use of these technologies for pretreatment of various lignocellulosic biomasses are given by (Mosier et al., 2005, Alvira et al., 2010, Kumar et al., 2009, Aita et al., 2010, and Taherzadeh et al., 2007).

Microwave irradiation has been widely used in many areas because of its high heating efficiency and easy operation. Advantages of microwave based technologies include reduction of process energy requirements, uniform and selective processing, and the ability to start and stop the process instantaneously (Datta et al., 2001 and Hu et al., 2008). The earliest known study involving microwave pretreatment examined the effect of microwave radiation on rice straw and bagasse immersed in water and reported an improvement in total reducing sugar production by a factor of 1.6 for rice straw and 3.2 for bagasse in comparison to untreated biomass (Ooshima et al., 1984). Some studies have shown that microwave irradiation could change the ultra structure of cellulose (Xiong et al., 2000) degrade lignin and hemicelluloses in lignocellulosic materials, and increase the enzymatic susceptibility of lignocellulosic materials (Hu et al., 2008, Xiong et al., 2000, and Azuma et al., 1984). Most microwave pretreatment is generally carried out at elevated temperature (>160°C). Some previous studies have shown that application of microwave irradiation pretreatment may significantly increase the conversion of starch materials to glucose (Zhu et al., 2006 and Palav et al., 2006). Combination microwave treatment with either acid or alkali or combined acid/alkali might be an alternative for pretreatment of lignocellulosic materials has been recently explored (Zhu et al., 2006, Hu et al., 2008 and Binodet al., 2012).

The present study focused on extraction of cellulose from selected five biomasses using microwave assisted alkaline pretreatment. A domestic microwave oven with low microwave power - 170W - was used for this experiment with pretreatment solution being Sodium hydroxide. Study was carried out to evaluate the performance of the microwave assisted pretreatment method by subjecting five selected biomasses; Corn leaves, Corn Husks, Bagasse, Guinea grass and Sugar cane leaves, to obtain the maximum cellulose percentage with optimum pretreatment concentration and minimum exposure time on selected range.
Table 1: Chemical composition of agro-industrial waste available

<table>
<thead>
<tr>
<th>Agro-Industrial waste</th>
<th>Moisture</th>
<th>Total solid</th>
<th>Ash</th>
<th>Cellulose</th>
<th>Hemicelluloses</th>
<th>Lignin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn straw</td>
<td>1.92</td>
<td>97.78</td>
<td>10.8</td>
<td>61.2</td>
<td>19.3</td>
<td>6.9</td>
</tr>
<tr>
<td>Sugar cane Bagasse</td>
<td>8.34</td>
<td>91.66</td>
<td>1.9</td>
<td>30.2</td>
<td>56.7</td>
<td>13.4</td>
</tr>
<tr>
<td>Guinea grass</td>
<td>-</td>
<td>-</td>
<td>31.0</td>
<td>22</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Notes: (%w/w) = percentage based on dry weight.
Source: (Rice straw, Corn straw and Sugar can bagasse (SciELO, 2014) and guinea grasses (Odedireet al., 2008).

2. MATERIALS AND METHODOLOGY

2.1 Materials
Sodium hydroxide (NaOH)
99% Hydrochloric acid (HCl)
Sodium Chlorite (NaClO₂)
Acetic acid, Acetone
Five selected biomasses-(Bagasse, Sugar cane leaves, Corn leaves, Corn husks, Guinea grass)
Desiccator
Microwave oven and Electric oven
Electric grinder
Analytical balance

2.2 Methodology
This method was performed by using a domestic microwave oven. Different concentrations of three pretreatment solutions (NaOH) and selected five different biomasses were used for the experiment.

Three prepared pretreatment (NaOH) solutions
(1) - 1.25 mol/L NaOH
(2) - 2.5 mol/L NaOH
(3) - 5.0 mol/L NaOH
Five biomasses;  
(1) - Bagasse  
(2) - Sugarcane leaves  
(3) - Corn leaves  
(4) - Guinea grass  
(5) - Corn husk  

Selected biomasses (Bagasse, Sugarcane leaves, Corn leaves, Guinea grass and Corn husk) were dried at 105°C using electric oven until a constant weight was observed and then ground using a normal grinder. Forty five treatments consisting of combinations of five biomass, selected three NaOH concentrations and selected three exposed time durations of microwave irradiation- (1)15minutes (2)30 minutes and (3)45 minutes were used. Each treatment was carried out three times. 10 ml from each prepared NaOH solution was added to 1g of biomass. According to that total of 25 g of biomass with 250 ml of NaOH solution was added to 500 ml beaker. Selected biomasses were immersed separately in 1.25mol/L NaOH, 2.5mol/L NaOH and 5 mol/L NaOH solutions and irradiated under a microwave power of 170W for 15, 30 and 45 minutes. The lower power level of domestic microwave ovens is 170 W was chosen following the results of work carried out by Galema et al., (1997). According to their findings, low power rate was allowed for sufficient lengths of pretreatment time without drastic volumetric losses of the liquid phase and no charring of the solid sample occurred during 45 minutes of treatment time. After pretreatment, biomasses were washed with tap water. The mixtures were kept immersed in 10% HCl for 4 hours, washed with tap water once and heated to 60°C using an electric oven and kept for 24 hours in a desiccator until a constant weight was reached. Percentages of weight losses were evaluated as weight different of before and after pretreatment of each biomass using an analytical balance. Cellulose percentages were determined using chlorination method as described by the Silverstein et al., (2007). 1g of sample was placed in a thermos flask (300ml) and 150 ml of distilled water was added. 1g of sodium chlorite (NaClO₂) and 0.2 ml of acetic acid were added while shaking slowly inside a shaking water bath with the flask covered with a glass lid and boiled at 70 °C to 80 °C for 60 minutes. Again, 1 g of NaClO₂ and 0.2 ml of acetic acid were added and boiled three more times. After cooling, the sample was filtered using filter papers and washed with hot water until free of acid. Afterward, the insoluble portion was dried in an oven at 60 °C for 4 h, cooled in a desiccator and weighed repeatedly until a constant weight was obtained. Holocellulose (combination of hemicelluloses and cellulose) content was calculated as follows.

Holocellulose content (%) = \( \frac{\text{Final weight after treatment}}{\text{Initial weight of sample}} \times 100 \)

Amount of cellulose was calculated after determination of holocellulose content by further treating the fiber obtained with sodium hydroxide and acetic acid. Hemicellulose content was calculated by subtracting the cellulose content from the holocellulose content. In addition, percentages of weight losses and cellulose were evaluated using Minitab version 14. Samples of Pretreated fibers with highest cellulose content were analyzed using Fourier Transformer Infra-Red Spectrometry (FTIR) to confirm extracted fibers were cellulose (sample were dried in an oven at 60 °C for 4 h, kept in a desiccator and weighed repeatedly until a constant weight was obtained prior to FTIR analysis).

2.3 RESULT AND DISCUSSION

Visual inspection shows that extracted fibers are thinner and straight after pretreatment. Normally formation of cellulose is of wool type, Hu et al., (2008) mentioned that this
formation indicates that the lignin degraded and increased the exposure of cellulose and hemicelluloses in the lignocellulosic materials after microwave assisted pretreatment.

The result of analyzed data for characteristic of percentage of weight losses as shown in table 2; biomasses, NaOH concentration, time and interaction effect of (biomasses × NaOH concentration) were significant for percentage weight losses. According to the result of percentage of cellulose as show in table 3 indicated that except for exposure time to irradiation and (NaOH concentration × Time), other data were significant for percentage cellulose.

Figure 2 and 3 indicated variation of “main effect plot” and “interaction plot” of percentage of weight loss of selected plant bio materials after microwave assisted alkaline pretreatment. According to those different percentage of weight losses occurred due to different composition characteristics of selected fibers as described in SciELO,(2014) and Odedire et al., (2008). Corn leaves and corn husk show highest weight losses and bagasse had lower percentage of weight loss due to effects of predominant presence of lignin content of native biomass. Also concentrations of NaOH affected percentage of weight losses. The present study shows that increasing NaOH concentration up to 1.25mol/L, 2.5mol/L to 5 mol/L increased the percentage of weight loss, Fang et al, (1999) has confirmed that the increasing alkaline condition in pretreatment solution resulted in an increase in the amount of lignin and hemicellulose solubilizing. The result of present study confirms their findings. The “main effect plot” and “interaction plot of percentage of cellulose “are shown in figures 2 & 4 and 3 & 5. According to that fibers extracted from corn leaves and corn husk show highest percentage of weight loss and lowest percentage of cellulose. The low content of lignin in corn straw may be the reason for highest amount of degradation of biomass due to solubilizing of lignin, hemicelluloses and also cellulose (syifarobbani., 2016). The results of present study indicated that NaOH concentration of 5mol/L applied treatment resulted in the highest amount of cellulose when compared to those with concentration of 1.25 mol/L and 2.5 mol/L. During delignification, the NaOH breaks the ester bonds cross-linking lignin and xylan, thus increasing the porosity of biomass (Silverstein et.al., 2007) and also increasing the amount of lignin and hemicellulose solubilizing. Sugarcane leaves show highest percentage cellulose and bagasse show lowest percentage of cellulose compared to those of other biomasses. All pretreated fibers using pretreatment of 5mol/L NaOH solution and 15 minute duration resulted in 65.2% - 85% of cellulose. Also preheating times of 15, 30 and 45 minutes only affected the loss of lignin, hemicelluloses and cellulose and there was no significant effect on percentage of cellulose. According to the result of this study, the optimum pretreatment condition for selected biomasses was found to be 5 mol/L NaOH and 15 minutes of 170W microwave dose. Comparison of results of FTIR analysis of extracted cellulose fibers from 5 mol/L NaOH and 15 minute pretreatment shown in figure 6(a,b) to 10 (a,b), confirmed that the structural changes of native and microwave assisted alkaline pretreated fibers compares well with those wave numbers in the findings of Wang et al.,(2007) and Pandey et al.,(2004) as shown in table 4. Major changes observed were broadening of band at 3200-3400 cm⁻¹ which was associated with the O-H stretching of the hydrogen bond in cellulose. The peak of ~CH2 stretching near 2900 cm⁻¹ were easily distinguishable from native as well as microwave assisted alkaline pretreated fibers in present study. According to the Sun et al., 2008, band at 1000 – 1200 cm⁻¹ were related to structural features of cellulose and hemicelluloses. The enhancement of absorption peak at
1000- 1100cm$^{-1}$ after pretreatment indicate the increase in cellulose content in solid residue. The peak of O-H bonds at 3400 cm$^{-1}$ stretching at 3300 cm$^{-1}$ are the distinguished features of cellulose. The O-H bond at 3400 cm$^{-1}$ is affected by microwave assisted alkaline pretreatment and its intensity is decreased in all extracted fibers. It has been reported that microwave irradiation enhances the saponification of intermolecular ester bonds cross-linking xylan the O-H band intensity tend to decrease due to its consumption in this reaction.

**Table 2: Variation of probability values (P value) of percentage weight losses of selected bio masses**

<table>
<thead>
<tr>
<th>Factors</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio mass</td>
<td>0.031</td>
</tr>
<tr>
<td>NaOH concentration</td>
<td>0.019</td>
</tr>
<tr>
<td>Time</td>
<td>0.035</td>
</tr>
<tr>
<td>Bio mass* NaOH concentration</td>
<td>0.000</td>
</tr>
<tr>
<td>Bio mass*Time</td>
<td>0.577</td>
</tr>
<tr>
<td>NaOH concentration*Time</td>
<td>0.261</td>
</tr>
</tbody>
</table>

**Table 3: Variation of probability values (P value) of percentage of cellulose of selected bio masses**

<table>
<thead>
<tr>
<th>Factors</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio mass</td>
<td>0.031</td>
</tr>
<tr>
<td>NaOH concentration</td>
<td>0.005</td>
</tr>
<tr>
<td>Time</td>
<td>0.180</td>
</tr>
<tr>
<td>Bio mass* NaOH concentration</td>
<td>0.002</td>
</tr>
<tr>
<td>Bio mass*Time</td>
<td>0.000</td>
</tr>
<tr>
<td>NaOH concentration*Time</td>
<td>0.062</td>
</tr>
</tbody>
</table>

**Table 4: Variation of FTIR characteristics of cellulose (Wang et al., 2007 and Pandey et al 2004)**

<table>
<thead>
<tr>
<th>Wave number (cm$^{-1}$)</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>3336</td>
<td>O-H stretching</td>
</tr>
<tr>
<td>2880 - 2940</td>
<td>C-H stretching in methyl and methylene groups</td>
</tr>
<tr>
<td>1734</td>
<td>C=O stretching in unconjugated ketones, carbonyls and in ester groups, frequently of carbohydrate origin.</td>
</tr>
<tr>
<td>1598</td>
<td>Aromatic skeletal vibration plus C=O stretch</td>
</tr>
<tr>
<td>1502</td>
<td>Aromatic skeletal vibration plus C=O stretch</td>
</tr>
<tr>
<td>1372</td>
<td>CH deformation in cellulose and hemicellulose</td>
</tr>
<tr>
<td>1316</td>
<td>C-H vibration in cellulose</td>
</tr>
<tr>
<td>1270</td>
<td>C-O stretch in lignin; C-O linkages in guaiacyl aromatic methoxy groups.</td>
</tr>
<tr>
<td>1235</td>
<td>C = stretch in lignin and xylan</td>
</tr>
<tr>
<td>1157</td>
<td>C-O-C vibration in cellulose and hemicellulose</td>
</tr>
<tr>
<td>1034</td>
<td>Aromatic C-H in plane deformation, C-O deformation; primary alcohol</td>
</tr>
<tr>
<td>897</td>
<td>$\beta$-glycosidic linkages</td>
</tr>
</tbody>
</table>
Figure 2: Variation of mean percentage weight losses with (a) biomass, (b) NaOH concentration and (c) time duration.

Figure 3: Variation of interaction plot percentage of weight loss a) (biomass × NaOH concentration), (b) (biomass × time) (c) (time × NaOH concentration)
Figure 4: Variation of mean percentage cellulose with (a) biomass, (b) NaOH concentration and (c) time duration

Figure 5: Variation of Interaction plot of percentage of cellulose (a) (Biomass × NaOH concentration), (b) (Biomass × time) (c) (Time duration × NaOH concentration)
Figure 6: FTIR results (a) Raw bagasse (b) extracted fibers from 5 mol/L NaOH pretreatment solution and 15 minutes
Figure 7: FTIR results (a) Raw Sugarcane leaves (b) extracted fibers from 5 mol/L NaOH pretreatment solution and 15 minutes
Figure 8: FTIR results (a) Raw Cornleaves (b) Extracted fibers from 5 mol/L NaOH pretreatment solution and 15 minutes
Figure 9: FTIR results (a) Raw Corn husk (b) Extracted fibers from 5 mol/L NaOH pretreatment solution and 15 minutes
Figure 10: FTIR results (a) Raw Guinea grass (b) Extracted fibers from 5 mol/L NaOH pretreatment solution and 15 minutes

CONCLUSIONS

Composition characteristics of native bio masses affected percentage of weight losses and percentage of cellulose after microwave assisted alkaline pretreatment. Increasing of alkaline concentration of pretreatment solutions resulted in high weight losses of the bio masses. Highest weight losses of plant biomaterials occurred in pretreated corn leaves and corn husk which also shows lower percentage of cellulose. All pretreated fibers using pretreatment 5mol/L NaOH solution and 15 minutes consisted of 65% - 85% of cellulose. Among them sugarcane leaves show the highest (84%) and bagasses (65%) show the lowest values.
Exposed time for irradiation was not significant in the formation of percentage of cellulose. According to the results, the optimum pretreatment condition for selected biomasses was found to be 5 mol/L NaOH and 15 minutes of 170W microwave dose within the pretreatment concentrations exposure to microwave radiation.

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