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ATINER is a ***World Non-Profit Association*** of Academics and Researchers based in Athens. ATINER is an independent **Association** with a **Mission** to become a forum where Academics and Researchers from all over the world can meet in Athens, exchange ideas on their research and discuss future developments in their disciplines, **as well as engage with professionals from other fields**. Athens was chosen because of its long history of academic gatherings, which go back thousands of years to *Plato's Academy* and *Aristotle's Lyceum*. Both these historic places are within walking distance from ATINER's downtown offices. Since antiquity, Athens was an open city. In the words of Pericles, **Athens*"…is open to the world, we never expel a foreigner from learning or seeing"*.** ("Pericles' Funeral Oration", in Thucydides, *The History of the Peloponnesian War).* It is ATINER's **mission** to revive the glory of Ancient Athens by inviting the World Academic Community to the city, to learn from each other in an environment of freedom and respect for other people's opinions and beliefs. After all, the free expression of one's opinion formed the basis for the development of democracy, and Athens was its cradle. As it turned out, the Golden Age of Athens was in fact, the Golden Age of the Western Civilization. *Education* and *(Re)searching* for the 'truth' are the pillars of any free (democratic) society. This is the reason why *Education* and *Research* are the two core words in ATINER's name.

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President's Message

All ATINER's publications including the e-journals are open access without any costs (submission, processing, publishing, open access paid by authors, open access paid by readers etc.) and are independent of the presentations made at any of the many small events (conferences, symposiums, forums, colloquiums, courses, roundtable discussions) organized by ATINER throughout the year. The intellectual property rights of the submitted papers remain with the author.

Before you submit, please make sure your paper meets some basic academic standards, which include proper English. Some articles will be selected from the numerous papers that have been presented at the various annual international academic conferences organized by the different divisions and units of the Athens Institute for Education and Research.

The plethora of papers presented every year will enable the editorial board of each journal to select the best ones, and in so doing, to produce a quality academic journal. In addition to papers presented, ATINER encourages the independent submission of papers to be evaluated for publication.

The current issue of the Athens Journal of Technology & Engineering (AJTE) is the second issue of the sixth volume (2019). The reader will notice some changes compared with the previous issues, which I hope is an improvement. An effort has been made to include papers which extent to different fields of Technology and Engineering.

Gregory T. Papanikos, President
Athens Institute for Education and Research

Athens Institute for Education and Research
A World Association of Academics and Researchers

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24-27 June 2019, Athens, Greece

The Civil Engineering Unit of ATINER is organizing its **9^{th} Annual International Conference on Civil Engineering, 24-27 June 2019, Athens, Greece** sponsored by the Athens Journal of Technology & Engineering. The aim of the conference is to bring together academics and researchers of all areas of Civil Engineering other related areas. You may participate as stream leader, presenter of one paper, chair of a session or observer. Please submit a proposal using the form available (https://www.atiner.gr/2019/FORM-CIV.doc).

Academic Members Responsible for the Conference

- **Dr. Dimitrios Goulias**, Head, Civil Engineering Unit, ATINER and Associate Professor & Director of Undergraduate Studies Civil & Environmental Engineering Department, University of Maryland, USA.

Important Dates

- Abstract Submission: **13 May 2019**
- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **27 May 2019**

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Details can be found at: https://www.atiner.gr/2019fees

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The Industrial Engineering Unit of ATINER will hold its 7th **Annual International Conference on Industrial, Systems and Design Engineering, 24-27 June 2019, Athens, Greece** sponsored by the Athens Journal of Technology & Engineering.The aim of the conference is to bring together academics, researchers and professionals in areas of Industrial, Systems, Design Engineering and related subjects. You may participate as stream leader, presenter of one paper, chair of a session or observer. Please submit a proposal using the form available (https://www.atiner.gr/2019/FORM-IND.doc).

Important Dates

- Abstract Submission: **13 May 2019**
- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **27 May 2019**

Academic Member Responsible for the Conference

- **Dr. Theodore Trafalis**, Director, Engineering & Architecture Division, ATINER, Professor of Industrial & Systems Engineering and Director, Optimization & Intelligent Systems Laboratory, The University of Oklahoma, USA.

Social and Educational Program

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Assessment of Supervised Drug Release in Cordial Embedded Therapeutics

By Adel Razek[*]

This paper targets to illustrate an assessment strategy of implanted therapeutics for restricted drug delivery with minimally invasive and non-ionizing user-friendly conditions. A functioning analysis indicates an image guided solution involving magnetic resonance imager (MRI). The paper then discusses MRI and investigates its environmental compatibility for embedded therapeutics. This investigation accounts for the nature of the different electromagnetic fields of the imager. We have also investigated the confrontation of the imager performance, the patient wellbeing and biological effects. We have verified the MRI environmental compatibility through EMC analysis of field perturbation due to implanted materials considering the conventional imager operation. EMC analysis 3D numerical applications support the contribution at the end of the paper. This study is a mixed of survey and modeling.

Keywords: *Implants, Minimally Invasive, Non-Ionizing, Imaging, EMC Analysis*

Introduction

A recent significant challenge concerns embedded therapeutics (Dash et al. 1998, Perry et al 2007, Bazaka et al. 2013, Amar et al. 2015, Eltorai et al. 2016, Ramachandran et al. 2017, Mao et al 2018).

Beside, some are using active locally restricted drug release technologies (Massiota et al. 2018, Okabe et al. 2003, Hsu et al. 2016, Hsu et al. 2014).

Embedded therapeutics constructions might use local treatment minimally invasive technologies with implants. These implants utilize drug delivery systems for intra or adjacent tissue covering a given zone.

Friendly wellbeing and security of patient infer minimally invasive technology. For embedded therapeutics, this indicates the use of biodegradable materials and wireless controlled actuation of implants.

Biodegradable structures are used in order to bypass a second surgical elimination of the devices and to avoid a recurring immune reaction of the external body (Okabe et al. 2003, Hsu et al. 2016, Hsu et al. 2014, Yun et al. 2009, Boutry 2012).

Wireless powering and control transfer consists of transferring energy and signals from an external source to the load without physical contact (Boutry 2012, Ding et al. 2014).

For kindly comfort of patient, the therapy should be accurately restricted to the affected zone. The accuracy of the restricted zone of therapy is related to the precision of implant actuation and hence the wireless transmission circuit. This accuracy is also much correlated to the exactitude of the implant tracking in the

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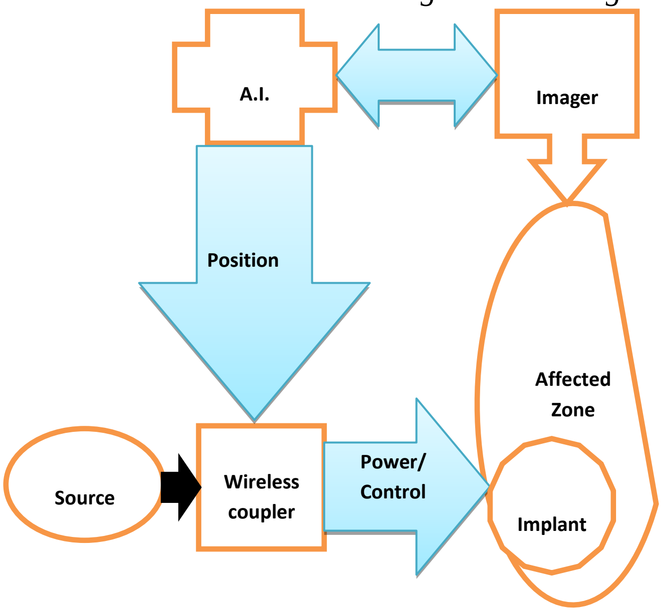
space. Therefore, the adequate key for such high-resolution topological survey is the image guided position detection of the implant in the space (Razek 2018).

This paper relates the details and the discussion of the different features covering the wellbeing and the security of patient in image guided embedded therapeutics. After the adoption of an adequate imager, the study will relay the performance and the environmental compatibility of the elements involved in the projected system. These concerns in particular the details of the elected imager constitutes as well as the basis of its functioning. These details, which are necessary for the achievement of the followed assessment strategy, would help in deepening the investigations developments. The paper ends by EMC computation examples supporting the imager environmental compatibility of the elements involved in the projected system.

Implanted Device and Imaging

As discussed in the introduction, the minimally invasive technology and the accurately restricted drug delivery suggest an image guided drug release embedded implant that one can power and control wirelessly by an external source. Such device may consist of an interactive system operating autonomously if integrates an artificial intelligence AI algorithm as shown in figure 1. Such system is supposed to operate under the survey of the medical team (Razek 2018).

Figure 1. *Interactive Autonomous Image Guided Drug Release System*



Non-ionizing Imaging

Different biomedical imaging technologies are available; they employ either, x-rays, sound, magnetism (Magnetic Resonance) or radioactive pharmaceuticals.

Each of these issues is more or less suitable for a specified situation. For conventional imaging circumstances where the exposure to the imager arrangement is limited in time interval there is no constraints relative to the nature of these imagers. Therefore, the problem of the ionizing radiations concerning some of these imagers does not impose any serious constraint.

In case of sustained exposure to the imager as in the case of image assistance therapeutic, only the magnetic resonance imager (MRI) and the ultrasound imager do not suffer of the ionizing radiations serious drawback (Tsekos et al. 2007). However, it is noteworthy that the ultrasound imager although radiation free, due to its functioning principle, it necessities an acoustic window (without air or bones).

The local delivery implant technology ought to use non-destructive biological and health undistinguished sensing. Thus, MR image guided technology seems to be an excellent and universal sensing candidate for embedded therapeutics (Razek 2018).

On the other hand, the use of the MR imager in image guided therapeutics as well as in other medical interventions assisted by imaging, implies two types of restrictions concerning its performance and environmental compatibility. This is due to the practice context of the imager concerning the treatment time interval and the proximity of the tools, necessary for the treatments, to the imager environment.

Concerning the treatment time interval, one notes that the time necessary to obtain an image is directly in relation to the performance of the imager and in particular, to the output of its gradient coils; we will discuss this point later in the paper. Higher the gradient output, the time necessary for an image is shorter, which is better for the outcome of the treatment. In the meantime, such high output increases the risk of negative biological effects for the patient. Therefore, we face a problem of finding the middle ground between the imager performance and the harmful biological effects.

For the proximity of treatment tools, it is worth mentioning that MR imager is very sensitive in connect with the electromagnetic noise and the introduction of certain external stuffs as magnetic or conductor materials in the imager environment; we will discuss this compatibility aspect in the next section.

Treatments Tools and Constraints in MR Imagers

One of most commonly used diagnostic tools is the MRI technology. Its use in a context gathered in therapeutic image assisted set, permits to achieve an excellent localising tool improving the therapeutics and allowing precise minimally invasive procedures under non-ionising environment. Thus, accomplishing a significant impact on clinical determinations and health consequences. Additional social challenges, in complement to the efficacy of image guided interventions and therapeutics, in different up-and-coming arenas of biomedical research are outstanding. For example, mapping of brain activity in neuroscience investigations and supervising advancement of reintegration therapies.

The Magnetic resonance imaging (MRI) technique delivers images of the biological tissue conditional on electromagnetic field. These images acquired throughout the arrangement of three kinds of electromagnetic fields: an intense static magnetic field, a low frequency pulsed little static magnetic space varying field (gradient), and a high radio frequency field. In a condensed manner, the tissue under an arrangement of field acquaintance, returns information that converted into signals that once again translated into images.

The MRI technique operates, as mentioned before, different electromagnetic fields with very different magnitudes and frequencies. The arrangements using such technology are very susceptible to electromagnetic noise and to the existence of magnetic or conductive substances that can produce image degeneration. Subsequently, actuating and mechatronic systems usually used in image guided interventions and therapeutics are not appropriate for MRI appliances, giving rise to a need for adequate type of schemes: MR compatible. Some MRI compatible specialised robots and micro-robots designed for particular interventions and therapeutics exist (N.V. Tsekos, et al 2007). We have to use magnetic released materials in the construction of robots that use distinct forms of actuation, which are MRI compatible.

The in depth analysis of the environmental compatibility as well as the confrontation of the performance and the constraints in MR image guided technology concerns the next sections. Due to this aim, one needs understanding the basic principle of such imager as well as going inside details of its components.

MRI Basis, Fields and Components

Due to clinical circumstances, MRI is principally utilized in favor of imaging of hydrogen (or further specifically the hydrogen nucleus that is a proton) confined in human body. Hydrogen stand in for 63% of the atoms of the whole body. A proton is a mass with a positive charge, which turns around an axis on itself. One can characterize its magnetic moment under the arrangement of a revolving vector on itself: this typifies the spin of the proton.

It is nevertheless likely to accomplish MRI using further nuclei than hydrogen, for instance phosphorus or sodium; however, their unimportant intensity in living tissues marks their revealing problematic in exercise.

Without a doubt, in human body, protons have arbitrarily orientations. Therefore, their resultant magnetic field is zero, and the living body does not present any magnetization. On the other hand, they do not revolve together; in other words, they behave out of phase.

Considering the MRI principle, the protons could do with three necessary arrangements in the interior of the examined part of the living tissue (S): bring into line all the protons in an unchanged direction, make them take tums simultaneously together in the volume S, and exactly so locate their distinct spatial origin.

Fields Utilized in MRI

As mentioned before MRI functioning principle imposes three necessary conditions.

The first arrangement consisting of aligning all the protons in the volume S could be achieved by placing the part S of the patient in a strong magnet to guide all protons in the axis of the static magnetic field B_0 of this magnet.

Considering the second one, to make the protons of the volume S rotate together we can supply them by an energy (excitation) under the form of a radio frequency wave B_1; the frequency of such wave should be identical to the natural frequency of rotation of protons (resonance). The value of this natural frequency f_L (Larmor frequency of protons) which is dependent of B_0, equals 42.5 MHz per tesla. The provided energy to the protons of S, not only synchronizes their rotation due to resonance phenomenon, but as well, fashions the ways of protons rocking a bit related to the axis of the magnet. The radio frequency wave disruption (relaxation) outcomes in the break out of axis rocking and synchronous revolution of the protons of the volume S. Associated to this phenomenon one can characterize the operation by two relaxation times respectively T_1 and T_2. Thus, go again to the original state, so the protons inside the volume S bring back energy that provided to them by the radio frequency wave. This restored energy is still in the form of a wave. It is likely to sense such a signal through an appropriate tuned radio frequency coil (antenna).

In the third arrangement, if one accurately locates the spatial origin of the signal, it is thinkable from there to institute a matrix image; a physical 3D location mapping of the volume S protons. Regarding such spatial localization, for each of the sections of spin in the volume S, it is possible to go through a distinctive magnetic field value. Thus, we would be capable to image their positions. To accomplish this we apply a 3D space gradient function under the form: $G(x, y, z)$ on the static magnetic field B_0 in the volume S. Therefore, engendering a continuing space variant in B_0 will outcome in a space magnetic field $B_0 (x, y, z) = B_0 + G(x, y, z)$, matching a space Larmor frequency of protons $f_L(x, y, z)$, allowing coding spatial image in the volume S. The obtained gradients are under the form of pulsations with a very low frequency repetition that produce a kind of shouting “Hammering". The radio frequency coil (antenna) being tuned to the space Larmor frequency of protons $f_L(x, y, z)$ in the volume S and matched (impedance adapted, classically to 50 Ohms). This frequency is variable in the volume S and generally one tune the coil to the frequency in compliance to the field applied in the center of the volume S.

From the above lines, we get the message that the MR imaging system use the services of three different electromagnetic fields to get hold of images of the inspected fragment of the body S. It is noteworthy that the natures of these three fields are completely different concerning the amplitude and the frequency as well as the presence during functioning. Under the classical operation of a MRI to insure the correct functioning of the imager, we have to protect and compensate both the static and the gradient fields. The radiofrequency field is the most vulnerable notably against electromagnetic perturbations and the introduction of certain external matters in the imager environment.

MRI Components

As mentioned in the last section, an MR imager has three indispensable components producing the stated three fields: magnet, gradient and radiofrequency. The majority of magnets are of the superconducting type whose responsibility is to engender a homogeneous static magnetic field inside the bore B_0. Three couples of gradients coils are acting in the three axes x, y, and z directions that make available the encoding of the space inside the bore. The radiofrequency coils produce electromagnetic fields at the Larmor frequency B_1.

The fields established by MRI components have different performs and belong in distinctive scales in terminologies of strength, frequency and duration. Because of these separate extents, it is conceivable to study on, a case-by-case basis, each of the three fields. .

It is possible to classify the radiofrequency coils or antennas into two sorts: surface and volume ones. The radiofrequency field B_1 is by principle in perpendicular orientation with that of the static field B_0. Comparing the two types of antennas, the volume one (called often birdcage) has a most important advantage that produces a uniform field inside the coil. As stated formerly an MRI is very susceptible to electromagnetic noise that can instigate image worsening. The insertion of magnetic or conductive stuffs in the neighboring environment of MRI could bring in such perturbation.

In the meantime, the electromagnetic environment that reflected unsympathetic, with intense static field, to which is place over high frequency and pulsated fields. We can define the MRI compatibility in relation to such environment. The device introduced in the MRI hosting must not disturb the field while it is in place, with the electronics powered and it is running. This demonstrates that we have to choose the device constituting materials judiciously, the electronics used must be of low pollution and the whole system optimized. Yet, investigational studies have shown that the insertion of small ferromagnetic or conductive parts (nuts, screws ...) could almost not disturb imaging. This is due to the conventional protection and compensations of the static and gradient fields as mentioned before. Finally, despite these constraints, the realized device must have a sub-millimeter resolution, which necessitates the employment of an adequately rigid stuff and appropriately precise actuation.

Take into account these requirements; we can design MRI compatible specialized robots constructions for particular interventions or therapeutics. These robots have to use MRI compatible actuation. Outstanding actuation applicants, particularly in medical therapeutics and chirurgical interventions, are using active smart materials (e.g. piezoelectric and magnetostrictive) actuators due to their supremacy in terms of accuracy, rapidity and mass.

Enhancement in the domain of image guided therapeutics and interventions count on the expansion, elucidation and acceptance of accessible MRI, actuators and robots for medical therapeutics and chirurgical make easier. Each of these constituents performs for a complicated equipment. The bringing together of these components to establish a new diagnostic tool supporting therapeutics and interventions ask for supplementary convoluted technologies. The investigation and analysis of such gathered device will allow defining imperatives covering the compatibility of the diverse constituents despite the fact that keep in good state the efficiency and dismissing the added cost of each one. Therefore, one can accomplish a negotiation of could do with compatibility extent respects within acceptable limits efficiency and extra cost. Because of these regards, one can enhance the clinical outcomes founded on the suggested diagnostic setting allowing milder health consequences for the patients and the medical staff, while be part of the cause of the sustainability of the health care organization.

MR Image Guided Therapeutics

The use of MRI in a context gathered in therapeutic assisted set, as stated before, permits to accomplish an excellent localizing tool refining image-based therapeutics and permitting accurate minimally invasive processes under non-ionizing environment. Thus, undertaking a substantial impact on clinical determinations and health consequences. On the other hand, the MRI even though radiation free, its operation must carry out high performance and in the same time low biological effects. In addition, the tools necessary for treatment should comply with the imager environmental compatibility.

MRI Performance and Biological Effects

Each of the three fields engaged in the MRI scheme link up with the physical parameters of biological matters.

Conceivably the securest one of the imager magnetic fields is the static one. From the existing literature, only the existence of ferromagnetic stuffs or pacemakers in the body of patients could engender wellbeing risks notably related to the contact with B_0

The second likely provider of risk of imager fields is the pulsated field gradients. Due to the augmenting request for ephemeral cycles with larger temporal and spatial resolutions, the renovation of up to date gradient structures has led in the latest years to amplify considerably the structure output (strength and slew rate) to reduce imaging time. Regardless of this, it is commanding to set appropriate edges for this gradient output to comprehend the arrival of disagreeable side effects for the patient. High output gradients provoke a oscillating electric field that may produce unlikable peripheral nerve stimulation (PNS) and/or cardiac stimulation. These electric fields, if of enough strength and duration, can instigate the excitation of the peripheral nervous system with symptomatically spatially restricted feelings of compression, irritating, or muscle astringent. On the other hand, PNS, which can be embarrassing even if not alarming to the patient, has a limit poorer than the strength expected for possibly life-menacing cardiac stimulation (Razek 2018). It is noteworthy that from the above lines we are in presence of an optimization challenge. The high imager performance related to its high output gradient coil is supposed to lead to shorter imaging time. This impulse in the direction of the wellbeing of the patient. In the meantime, this high output could cause harmful biological effects which thrusts in the opposite direction of the patient wellbeing.

Radio frequency power amassing matches to the greatest danger for patient security in MR imager exams. The specific absorption rate (SAR) functioned in MRI inspections could be of 9 W/kg and for short sufficient interval so as generating less than 1°C inside body temperature rise. A local growth in temperature of 1°C in a healthy subject is totally out of hazard; thus, the MRI SAR ranks are below the limits announced by international security references.

This debate displays that awareness of the security of magnetic resonance imaging schemes can aid optimize both the safety and effectiveness of structure process. Characteristic values typifying the three different fields in MRI (Intensity, frequency and duration) (Tsekos et al. 2007) are:

B_0: 0.2–7 T, 0 Hz, Always present
Gradient: 0–50 mT/m, 0–10 kHz, multiple pulses of few ms
B_1: 0–50 μT, 8–300 MHz, Amp. Mod. Pulses of few ms

MRI and Environmental Compatibility

Magnetic resonance imaging (MRI) system employs static magnetic field, magnetic field gradients and fast evolution of radio frequency pulses.

The static magnetic field should be homogeneous and the magnetic field gradient (location dependent magnetic field) should be controlled and uniform. These two fields need compensation and correction to meet these conditions for conventional operation of the imager. The radio frequency wave has a frequency identical to this of rotation of protons (Larmor frequency of protons) which is dependent on the static field value and given by 42.5 MHz per tesla.

The MRI device is very sensitive to electromagnetic noise that can cause image deterioration. The introduction of magnetic or conductive materials in the close environment of MRI contributes significantly to such electromagnetic noise. The MRI-compatibility definition is in relation to such environment.

Therefore, in embedded therapeutics the implant is supposed to employ MRI-compatible materials and must utilize MRI-compatible actuation (Razek 2018, Tsekos et al. 2007, Chinzei et al. 1999, Khairi et al. 2016, Hariri et al. 2014, Su et al. 2018, Hariri et al. 2015, Khan et al. 2016, Dagdeviren et al. 2016, Lemair et al. 2015, Stapleton et al. 2017).

EMC Analysis and Formulation

Electromagnetic compatibility - EMC analysis aims to determine the impact of introducing in the MRI environment different materials and structures used in embedded therapeutics. For EMC analysis, we could consider different electromagnetic mathematical formulations and techniques (Ren et al. 2000, Ouchetto et al. 2007, Ren et al. 1990).

Expressions (1-4) give the basic full-wave electromagnetic formulation (Razek 2018):

$$\nabla \times \mathbf{H} = \mathbf{J} \qquad (1)$$

$$\mathbf{J} = \sigma\mathbf{E} + j\omega\mathbf{D} + \mathbf{J}_e \qquad (2)$$

$$\mathbf{E} = -\nabla V - j\omega\mathbf{A} \qquad (3)$$

$$\mathbf{B} = \nabla \times \mathbf{A} \qquad (4)$$

Where **H** and **E** are the magnetic and electric fields, **B** and **D** are the magnetic and electric inductions, **A** and V are the magnetic vector and electric scalar potentials. **J** and $\mathbf{J}_e$ are the total and source current densities, σ is the electric conductivity and ω is the frequency pulsation.

The 3-D solution of (1 to 4) permits to determine the perturbations in electromagnetic fields due to the introduction of external matters in a given system for a frequency pulsation (Wang 2017). Such impact permits to check the bounds of the system operation alteration (Razek 2018).

Application in MRI Environment

The analysis described in the last section could be achieved with the help of discretized 3-D finite element model (Ding et al. 2014, Khairi et al. 2016). Considering compensated static field and gradient field as described before, the interaction of different hosted materials constituting the embedded implant in the MRI environment with radio frequency magnetic field has been investigated (Razek 2018).

Simulation Conditions

The simulation system consists of a birdcage coil of 30 cm diameter and 30 cm length embedding a material or a structure of a cubic form of 5x5x5 cm^3, placed inside a 60 cm diameter tunnel. The birdcage coil generates a radio frequency field (at frequency 63.87MHz). This frequency corresponds to the Larmor frequency of protons in a static field of 1.5 T.

One can compute the radio frequency field distribution in the tunnel using 3D Edge Finite Elements discretization of the field **E.** To take into account the skin effect in case of conductor, a surface impedance boundary condition is used. The system's boundary (tunnel bore) is considered as a perfect conductor in which the field cannot penetrate.

We can check the different materials composing embedded implants including their actuation with the help of the simulation system.

umerical Results

In a previous work (Khairi et al 2016) concerning robotized interventions, we have verified the use of piezoelectric actuators in robot arms for multilayer actuators composed of PZT layers and aluminum plates with a very trivial thickness. The results confirmed that one could significantly reduce the perturbation, mainly due to conductors, by adjusting the position of the actuator axis relative to the field direction.

Concerning the present work we consider two categories of materials which are commonly used in implant actuation: piezoelectric and conductor materials of organic or non-organic nature. We can calculate the magnetic field distribution inside the tunnel for two examples of these materials. The first is a piezoelectric (μ_r = 1.0, ε_r = [450 990 990], σ = 0 S/m). We note that the piezoelectric permittivity is a vector (anisotropic) whose value is smaller in polarization direction than the two other directions. The second is a conductor (μ_r = 1.0, ε_r = 1.0, σ = 3.77e7 S/m).

Figure 2 shows the radiofrequency magnetic field (vertically directed) distribution in the axial cross section of the birdcage inside the tunnel for the reference case: no material.

Figure 2. *Radiofrequency Magnetic Field (Vertically Directed) Distribution in the Reference Case: no Material*

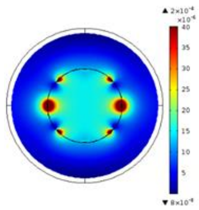


Figure 3 shows the magnetic field distribution for the case of introducing a 5x5x5 cm^3 piezoelectric material volume. It shows, compared to the reference case, that the piezoelectric has a small effect on the field (very small values of displacement currents).

Figure 3. *Radiofrequency Magnetic Field (Vertically Directed) Distribution in the Case of Piezoelectric Material*

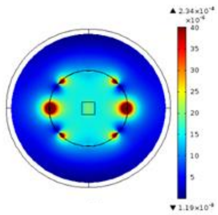
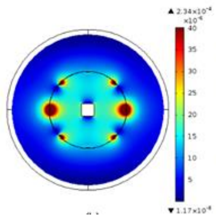


Figure 4 shows the magnetic field distribution for the case of introducing a conductor material volume. It shows, compared to the reference case that the conductor modifies significantly the field distribution due to the induced eddy currents in the conductor.

Figure 4. *Radiofrequency Magnetic Field (Vertically Directed) Distribution in the Case of Conductor Material*

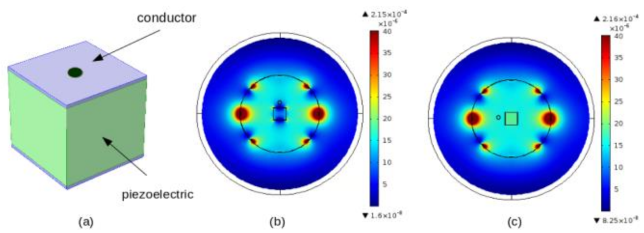


It is noteworthy that the degree of perturbation of the field in the conductor case is proportional to the significance of the conductor surface perpendicular to the field direction.

Investigating the relation between the degree of perturbation of the field due to the conductor and the surface of this last perpendicular to the field direction, the case of a non-conductor material coated by very small thickness plates of conductors, has been considered. In practice, this is the case of electrodes (conductor) to allow the supply of energy (Hariri et al. 2014, Su et al. 2018, Hariri et al. 2015).

We considered the case of a piezoelectric material as in figure 3 but coated on 2 opposite faces by conductor thin electrodes. We have computed the field distributions for the two cases where the electrodes are perpendicular and parallel to the field direction. Figure 5 shows the field distributions for these cases. The results confirmed that the direction of the conductor plays an important role. We can reduce significantly the impact of the conductor when it is parallel to the field.

Figure 5. *Radiofrequency Magnetic Field distribution in the Case of Piezoelectric with Electrodes (a) Material Configuration (b) Field Distribution when Conductors are Perpendicular to the Field (c) Field Distribution when Conductors are Parallel to the Field*



Conclusion

In this work that is a mixed of survey and modeling, we have investigated the issues of minimally invasive technology, accurately restricted drug delivery and non-ionizing detection in implanted therapeutics. The result suggests an image guided interactive solution with MR imager. The MRI compatibility of the embedded materials is then considered. We have also discussed the compromise of the imager performance, patient wellbeing and harmful biological effects.

For the sake of MRI compatibility, we have performed an EMC analysis considering the nature of different MRI fields and their conventional protections and corrections. We have investigated the impact of the presence of different matters composing implants in MRI environment. The first results elucidate that organic or non-organic piezoelectric and conducting materials could be tolerable in MRI environment by handling their space locating in the field orientation.

Future research focuses on the nature and size of materials involved in implanted therapies that recognize the well-being and safety of the patient. At the same time, these materials have a duty regarding acceptance in the MRI environment.

Concerning the nature of these materials, it can be generally of the active type (smart materials). The external source of wireless excitation acting on these materials can be a field (magnetic or electric) of low intensity so as not to disturb the operating fields of the imager. An open question of research concerning such a field of excitation, could it be linked to the operating fields of the imager? This is a delicate case with regard to the sequences and scales of these fields as well as their possible disturbances.

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A Relationship between Operational Status of Equipment and Technical Proficiencies of Aeronautical Engineering Students: A Case Study

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All students in the Aeronautical Engineering Technology program of Purdue University's School of Aviation and Transportation Technology are required for graduation to complete a reciprocating engine overhaul course. This study examined the relationship between engine operational status and students' technical competencies after a semester of maintenance practice on the engine. The tests were administered by laboratory instructors to determine whether there was a difference with technical competency with students who serviced operational engines verses nonoperational engines. Competency tests in the study were modeled from the Federal Aviation Administration (FAA) requirements for the practical test questions from the Airframe and Powerplant Certificate (A&P) examination. The tests were formatted and measured based on the criteria outlined in the Federal Aviation Administration's Aviation Mechanic Powerplant Practical Test Standards (FAA-S-8081-28A).

Keywords: *Aeronautical Engineering Technology, Aviation, Equipment, Hands-On Learning, Project-Based Learning.*

Introduction

The aviation industry is currently experiencing unprecedented growth. Boeing's Pilot and Technician outlook for 2018-2037 projects that 754,000 new maintenance technicians will be needed to maintain the world's aircraft fleet. North America will experience the second largest demand for maintenance personnel by requiring at least 189,000 new maintenance technicians (Boeing 2018). As the market continues to become more competitive, companies will look for their workforce to be the competitive differentiator. Companies will be looking for professionals who already have the required skills and can be trained quickly to meet operational requirements.

Many industry professionals predict that the demand for maintenance technicians will surpass the supply as soon as 2022 in the United States (Prentice and Costanza 2017). Due to the expected rapid fleet growth in Asia, Prentice anticipates that the effects of the shortage will be seen much sooner in Asia. One of the leading causes for the shortage of maintenance technicians is due to the aging maintenance technician workforce. In the US, the median age of an aviation mechanic is 51 years old. Within the next decade, many of the

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aging maintenance technicians will be eligible to retire. The United States government has recognized the upcoming critical shortage (Walsh 2018). Senators Jim Inhofe, Richard Bluementhal, Jerry Moran, and Maria Cantwell are all sponsoring the Aviation Maintenance Workforce Development Pilot Program. The Aviation Maintenance Workforce Development Pilot Program will financially support workforce development initiatives for students through scholarship programs, veteran transition programs and enhancing aviation technical education.

Purdue University's School of Aviation and Transportation Technology (SATT) in Indiana, United States of America, has been training future maintenance technicians in order to close the gap between supply and demand since the 1940s. The School of Aviation and Transportation Technology (SATT) at Purdue University prides itself for training career-ready emerging maintenance technicians for the aviation industry. However, the school offers more than just aviation maintenance certification. Students enrolled in the School of Aviation and Transportation Technology (SATT) can pursue a bachelor's or master's degree in Aviation Management, Aeronautical Engineering Technology (AET), Unmanned Aerial Systems, or Professional Flight Technology. The Aeronautical Engineering Technology degree program blends ABET, Inc. accredited engineering teachings and aviation maintenance practices to train a well-rounded aviation professional. Upon completion of the program and in addition to the bachelor degree) most Aeronautical Engineering Technology students are eligible to receive a 14 CFR Part 147 (Aviation Maintenance Technician Schools) training certificate and qualify to take the tests for the Federal Aviation Administration (FAA) Airframe and Powerplant Certificate (A&P). As the needs of the industry continue to grow, the School of Aviation and Transportation Technology continues to increase enrollment of all programs to accommodate those needs.

Aeronautical Engineering Technology degree courses are structured with both lecture and laboratory periods. Lectures focus on teaching principles, major concepts, and engineering theory while laboratories serve as time for students to apply these concepts and gain competency through practical engineering and maintenance projects. Aeronautical Engineering Technology students spend hundreds of hours in laboratories throughout their degree studies to apply and practice maintenance concepts that were introduced to the students in lecture.

One required course for the Aeronautical Engineering Technology program is a specialized reciprocating engine overhaul course. In that course, students are taught engineering and maintenance concepts regarding inspection, troubleshooting, repair, and overhaul. The laboratory is set up in a hangar with reciprocating engines on engine stands. Some engines are operational while some are not due to the engine's intended educational purpose or the restriction of resources. Student groups are randomly assigned to engines and must complete overhaul tasks through structured project-based learning that includes receiving inspection, disassembly, cleaning, final inspection, and reassembly. At the end of the overhaul process, the operational engines ran to ensure that the overhaul process was done and met required standards. All students, regardless of engine assignment, have an opportunity to run an operational engine throughout the semester.

Through the years, it has been noted that students assigned to engines that are nonoperational seem to feel less pressure to perform the maintenance tasks correctly and thoroughly because at the end of the semester their engine is not expected to run again. This study hypothesizes those students that perform maintenance procedures on operational equipment perform work that is of higher technical competency because of the increased pressure of having to return the engine back to service. Students' work that is performed on nonoperational equipment is of lower technical competency because there is no pressure to have the equipment operational again. Therefore, the implications of operational equipment vs. nonoperational equipment are very large and impactful on students' maintenance training and education.

Understanding the implications of operational equipment with regards to student learning is very important and has implications on key financial decisions on whether to keep current equipment operational or look at alternative methods for student training.

Literature Review

Project-based learning is used in Engineering Technology curriculum and 14 CFR Part 147 training at Purdue University's School of Aviation and Transportation Technology, because of project-based learnings' benefits over other teaching methods being widely accepted and recognized. Traditional teaching methods create barriers that prevent students from optimizing the instruction with their prior knowledge. Some other barriers to learning that students might experience from traditional teaching methods can include lack of motivation and engagement (Robinson 2013). Robinson surmises that these barriers exist because the student might not understand the importance and relevancy to the work. Robinson outlines the methods to project-based learning. The most significant requirement of project-based learning is the implementation of complex, authentic tasks. Robinson defines this "complex, authentic tasks" as work that would be appealing to someone outside of the class. There are also other important criteria for successful project-based learning. These criteria include students deciding how to accomplish the project as well as collaboration in a team environment. Robinson states that each of these steps is equally important when planning project-based coursework. Allowing students to feel in control of their own work and being accountable for the results is essential with project-based learning.

Project-based learning is a tried and true learning method according to Shin (2018). Shin's students participate in project-based learning because they are able to use their own experiences to tackle the problems assigned to them. Shin also explored the connections between student motivation and cooperation when using project-based learning methods and found that project-based learning positively motivates students and also increases their levels of cooperation. Furthermore, Shin found that the students' perceptions of project-based learning were positive.

The traditional educational methods of essay writing and memorization have been found to disrupt the creative process and natural conversations that occur between students and teachers when learning (Behizadeh 2014). Project-based learning aims to fill the gap by getting students and instructors to interact more naturally. Behizadeh also mentions that in order to facilitate learning, teachers need to ask their students to draw upon prior knowledge. This method is called problem-posing education. Problem-posing education is the perfect lead into project-based learning. Problem-posing is at the center of project-based learning. Students can create projects in order to solve problems and there is great benefit from problem-posing because learning through memorization and essay writing without project-based learning has proven to be less effective.

Rahman et al. (2017) explored the implications of project-based learning. The researchers found that 75 percent of students who utilized project-based learning in the study showed signs of problem-solving ability improvement. In addition, students who were taught through project-based learning showed improvement of their ethical character. The experimental class in the study showed a higher average improvement in proper ethics than the control class.

In addition to higher levels of cooperation and ethics, students are also able to develop professional skills when participating in a project-based learning curriculum. Johnson and Ulseth (2017) acknowledged the shift to emphasize professional competencies development by students. Then the authors also explored the experiences that the students have when professional competency skills are prioritized as learning outcomes for students in the courses. Johnson and Ulseth found that there is an increase in performance of professional competencies by students who participated in project-based learning over students who used traditional styles and methods. Students who participated in Johnson's and Ulseth's study were also able to better explain professional competency expectations with regards to the work place than the control group. This is reinforced by the student's exploration and reflection of professional identity within projects that cannot be reached through traditional methods of learning.

In order for instructors to implement project-based learning, there is a classical pedagogy to follow. Hwang et al. (2017) say that there should be 7 core stages to project-based learning. Only five stages are recognized currently. They are preparation, implementation, presentation, evaluation, and revision. The authors suggested that two additional stages be added because the current model lacks the ability to reach the learning outcomes of typical Capstone courses. Thus the new model should be preparation, conception, design, implementation, operation, evaluation, and revision. The old model lacks two features that build creative thinking skills and design process. They tested their new model on a capstone course and found that the students demonstrated significantly increased creativity skills and kept a more systematic record and analysis of all creativity tasks that were required for the capstone.

Unfortunately, developing curriculum for each of the stages of project-based learning is not the only barrier to implementation. An education institution's support is also very important for the success of project-based implementation within the curriculum. In Hong Kong project-based learning is being implemented feverishly (Lam et al. 2010). Lam explained this trend of sudden transition is because of the need to equip students with critical thinking and collaborative skills before graduation. The implementation process of project-based learning in learning institutes is further explored by Lam. 182 secondary-level teachers from Hong Kong were asked to complete a questionnaire about school support with regards to the transition as well as their own personal motivation towards implementing project-based learning. The results of the questionnaire stated that teachers were more motivated to implement project-based learning when they felt that their school was supportive of them. This means that instructors will feel more compelled to undertake a large project such as redesigning the curriculum and teaching methods with institutional support.

As stated in the introduction, Purdue University's School of Aviation and Transportation Technology partakes in project-based teaching methods. These teaching methods go hand in hand with the Federal Aviation Administration's expected learning outcomes for an individual pursuing a Federal Aviation Administration's Airframe and Powerplant certificate. The Federal Aviation Administration provides guidelines for the certification of airframe and powerplant mechanics. In order to complete the certificate, candidates must pass written, oral and practical tests for general, airframe, and powerplant subjects. The experimentation for this study was developed referencing the Federal Aviation Administration document, FAA-S-8081-28A, the Aviation Mechanic Powerplant Practical Test Standards and keeping all FAA criteria and standards in mind. To collect research data, the FAA guidelines were chosen to evaluate students on practical projects because they are the minimum and baseline standards of competency within the aviation industry.

The FAA defines three performance levels that must be assessed during the practical test. Each performance level and the definitions of the level are listed below:

> Level 1 – Know basic facts and principles. Be able to find information and follow directions and written instructions. Locate methods, procedures, instructions, and reference material. Interpretation of information not required. No skill demonstration is required.
> Level 2 – Know and understand principles, theories, and concepts. Be able to find and interpret maintenance data and information, and perform basic operations using the appropriate data, tools, and equipment. A high level of skill is not required.
> Level 3 – Know, understand, and apply facts, principles, theories, and concepts. Understand how they relate to the total operation and maintenance of aircraft. Be able to make independent and accurate airworthiness judgments. Perform all skill operations to a return-to-service standard using appropriate data, tools, and equipment. Inspections are performed in

accordance with acceptable or approved data. A fairly high skill level is required (FAA 2012).

Additionally, FAA-S-8081-28A defines satisfactory performance and unsatisfactory performance that the Designated Mechanic Examiner (DME) must use to assess candidates. Satisfactory performance is achieved if the applicant demonstrates the prescribed proficiency in the assigned elements in each subject area to the required standard. Applicants shall not be expected to memorize all mathematical formulas that may be required in the performance of various elements in this practical test standard. However, where relevant, applicants must be able to locate and apply necessary formulas to obtain correct solutions.

Unsatisfactory performance is diagnosed by the Designated Mechanic Examiner (DME) if the candidate does not meet the standards of any of the elements performed (knowledge or skill elements), failing the associated subject area, and thus failing the section of the practical test. Typical areas of unsatisfactory performance and grounds for disqualification include the following:

1. Any action or lack of action by the applicant that requires corrective intervention by the examiner for reasons of safety.
2. Failure to follow acceptable or approved maintenance procedures while performing skill (practical) projects.
3. Exceeding tolerances stated in the maintenance instructions
4. Failure to recognize improper procedures.
5. The inability to perform to a return to service standard where applicable
6. Inadequate knowledge in any of the subject areas.

"The inability to perform to a return to service standard where applicable" will be explored by testing students while using operational equipment and nonoperational equipment. Students will be assigned a practical project that they must demonstrate to an instructor. Competency of the student will be assessed based on the Federal Aviation Administration's criteria described above.

The practical project will be selected from the FAA subject testing outlined in Section IV – Powerplant Theory and Maintenance subsection A. Reciprocating Engines. The FAA requires that all applicants be able to exhibit knowledge in a wide variety of topics regarding reciprocating engine theory. The FAA also outlines skills to perform and what competency levels must be achieved by an applicant. Those objectives include demonstrating skill to perform engine overhaul concepts, inspection techniques, and other maintenance repairs.

Methodology

IRB process: This study participated in the Institutional Review Board (IRB) process. The IRB serves to protect human subjects participating in research studies

(University of Pittsburgh 2018). This study complied with all criterion of the IRB that governed this research.

Participants: Students enrolled in the Advanced Reciprocating Engine Overhaul course were tested. There were a total of 32 students. The students were assigned into two groups by laboratory section. Students within the sections were divided into groups of eight. The students in each section were first tested on operational equipment and then retested on the nonoperational equipment. The other half of the students were tested first on nonoperational equipment and then tested again on operational equipment.

The students sampled came from a diverse background. As seen in Table 1, the majority of the students are ages 21-22 years old. The sample comprises mostly of seniors due to the course being offered later in the curriculum. Twenty-one of the students who were in the class started their college career at the School of Aviation and Transportation Technology instead of transferring or Change of Degree Objective (CODO) into the program. CODO is the official process for students to transfer to a different area of study. Eleven students who were in the class had transferred or CODO in from another programs. Out of the thirty-two students, twenty-eight students plan on pursuing a career in the aviation industry. Finally, all but three of the students are planning on eventually testing for their Federal Aviation Administration's Airframe and Powerplant certificate.

Table 1. *Student Demographics*

<table>
<tr><td rowspan="2">Age</td><td>19-20</td><td>21-22</td><td>23-24</td><td>25-26</td></tr>
<tr><td>3</td><td>25</td><td>3</td><td>1</td></tr>
<tr><td rowspan="2">Class</td><td>Freshmen</td><td>Sophomore</td><td>Juniors</td><td>Seniors</td></tr>
<tr><td>0</td><td>1</td><td>6</td><td>25</td></tr>
<tr><td rowspan="2">CODO</td><td colspan="2">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="2">11</td><td colspan="2">21</td></tr>
<tr><td rowspan="2">Career in Aviation</td><td colspan="2">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="2">28</td><td colspan="2">4</td></tr>
<tr><td rowspan="2">Pursuing A&P</td><td colspan="2">Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="2">29</td><td colspan="2">3</td></tr>
</table>

While there are a variety of projects to choose from, all students in the overhaul laboratory for the semester were tested using projects with a Federal Aviation Administration defined competency level of 3. In addition to measuring competency level, the time that each student took to perform the skill was recorded as well as whether they had ever performed the task and when they had last performed the task.

T-Test: A series of t-tests with two-tail distributions and equal variance assumed were performed as an analysis on the data in order to test the hypothesis of this study. The tests can be utilized when there are two sets of data and the sample size is as small as 10 and is not typically used for larger sample sizes (Kenton 2018). Since the sample size was 32, a t-test was chosen over other statistical analysis tests.

Conducting this analysis on data allows the data from two separate data sets to be compared. This is helpful in determining if the data came from the same population. The t-test takes a sample from each set and assumes a null hypothesis first. After that, the test is calculated using the mean difference from each data set, the standard deviation of each set, and the number of values of each datasets. The tests compared both time to finish a project in minutes and its result in pass/fail format. Passing grade was recorded as 1, failing in the task as 0. Each student participated in both scenarios, working with operational and nonoperational engines.

Discussion

For time to finish, no statistical difference was found between the groups: students performing on operational engines (M = 22.28, SD = 14.21) and those who worked on nonoperational engines (M = 25.03, SD = 15.26), $t(62) = -0.75$, p = n.s.

For results of the tests, no statistical difference was also found between the groups: students performing on operational engines (M = .84, SD = .37) and those who worked on nonoperational engines (M = .72, SD = .46), $t(62) = 1.20$, p = n.s.

Based on those findings, it is possible to claim that there is no difference between preparing and testing the students on both operational and nonoperational engines. This outcome disproves the original hypothesis that equipment operational status would improve students' performance because of the increased pressure to restore the engines to airworthy condition. The data also showed that students took longer on equipment that was not operational. However, the longer amount of time could potentially be caused by the student not being fully focused and mentally relaxed while performing the practical project knowing that the project will make very little to no difference to the operating condition of the engine the student is working on. In order to better understand the current phenomenon, further studies need to be performed.

Conclusions

Further exploration with additional test data should be done to determine whether a larger sample size would impact the practical project results. Additionally, the researcher should interview the students to gather feedback and gain further understanding regarding the students' experiences testing on operational and nonoperational equipment. The student interviews can possible provide insights as to why there was no statistical relation between equipment operational status and students' technical competency. Further studies are needed in order to determine the cause of the unexpected results. If further studies consistently prove that there is no statistical relation between equipment operational status and students' technical competency, this may help training organizations determine that funding for equipment and training might be better allocated elsewhere than ensuring reciprocating engines are operational. Training funding can be spent on cheaper and easier to maintain alternatives such as engine mock-ups.

Since the 1940's, NASA and the US Air Force broadly recognized computer simulation as a preparation tool to reduce errors and decrease associate risks (Gerathewohl 1969, Allerton 2010). In the last eight decades, computer technology has changed drastically. This change has led to an acceptance of the computer-based pilot training as a primary method of preparation from the beginning to certification (Macchiarella et al. 2006). It was also confirmed that computer-based pilot training effectively transfers the positive psychomotor skills (Reweti 2014). Based on those examples, there is an opportunity to use advance simulation technology such as the integration of augmented reality (AR) and virtual reality (VR) into aeronautical engineering preparation and maintenance training. However, further studies are also required to determine the effectiveness of these alternative technologies.

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Experimental Investigation of Crystalline Silica in Concrete

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In construction industry, one of the most common materials is concrete. To increase strength and durability, various additives have been used in the industry. Crystalline Silica which has fine particles is one of these additives widely used in concrete construction. In the US, roughly 2.5 Million people are dealing with concrete in manufacturing concrete blocks, concrete cutting, or other concrete related activities such as trending, drilling, cutting, or sawing concrete. The Occupational Safety and Health Administration (OSHA) has recently stated that, Crystalline Silica in concrete is hazardous to human health. The people in risk are inhaling the silica particles and may develop silicosis, lung cancer, chronic obstructive pulmonary disease, or kidney diseases. Recently, OSHA developed new respirable crystalline silica standards for construction. With this new regulation, Crystalline Silica quantities will be limited. With this motivation, this research work deals with an experimental investigation of concrete ingredients to identify the effects of silica in construction. The paper experimentally investigates the effects of crystalline silica in concrete. The current design standards have been studied to reveal the efficiency of the silica in concrete. Compression strength and velocity tests have been used in the experimental set up. A better identification of the silica effect in concrete will help in decision process for the stakeholders in concrete industry.

Keywords: *Concrete Characteristics, Concrete Mix Design, Crystalline Silica, Crystalline Silica Concentration Test.*

Introduction

Concrete supplies are available in a variety of spectrum for transportation, building and other construction purposes. In the construction industry, concrete is one of the most important materials. Concrete as a material is needed for various purposes in construction regardless of the construction type. In the concrete production, cement is the most important ingredient. Besides the cement, a large amount of industrial byproduct material is in use (FHWA 2016). These byproducts include fly ash from the coal burning power plants, slag from the manufacture of iron and crystalline silica from the metal industry (ACI 224 2007, ACI 301-10 2010).

Occupational exposure to crystalline silica dust occurs is considered hazardous. Toxic chemicals, particulates and other harmful emissions in the workplace can cause significant hazards to workers. Identifying these potential hazards through research is very important to understand the solutions for such a problem. First, it should be understood what the optimum mixture is for concrete

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production and how we can reduce the effects of crystalline silica on workers (OSHA 2018a). According to Occupational Safety and Health Administration (OSHA), silica exposure remains a serious threat to nearly 2 million workers, including more than 100,000 workers such as abrasive blasting, foundry work, stonecutting, rock drilling, quarry work and tunneling. The seriousness of the health hazards associated with silica exposure is demonstrated by the fatalities and disabling illnesses that continue to occur (OSHA 2018b).

With the recent research, crystalline silica has been classified as a human lung carcinogen material. Additionally, breathing crystalline silica dust can cause serious illnesses. The respirable silica dust enters the lungs and causes various diseases including tuberculosis and silicosis and currently, there is no cure for silicosis. Workers who inhale these very small crystalline silica particles are at increased risk of developing serious silica-related diseases.

OSHA has issued two new respirable crystalline silica standards: one for construction, and the other for general industry and maritime. OSHA has begun enforcing most provisions of the standard for construction on September 23, 2017 and has begun enforcing most provisions of the standard for general industry and maritime on June 23, 2018 (OSHA 2018a). Therefore, it is important to discuss the crystalline silica. This paper discusses the effects of crystalline silica in the current design on the characteristics of concrete. An experimental setup was established for the research. Velocity and compression strengths were recorded.

Silica in Construction

In construction industry, silica is in the form of combination of alkali which is considered as the concentration of concrete. When alkali is in the presence of silica hydroxyl, there is an expansion occurs, that may cause some unwanted cracks. Such issues are the main reasons for the alkali cement in low percentage is used in the presence of silica fume. Silica fume is a pozzolan material having cement properties in the wider spectrum. Silica fume acts as if it were cement because there are small particles, having silicon dioxide. Surface area can make the admixture active pozzolan if the contact area is more.[1]

When concrete has silica fume, the strength of the section is increased gradually. Since silica fume is resistant to corrosion, concrete with silica fume is preferred to use in highway constructions, such as bridges and in rehabilitating existing structures.

In the US, about 2.5 million people are facing with respirable crystalline silica in their workplaces. In specific, there are about two million construction workers who drill and cut silica-containing materials such as concrete and stone, and 500,000 workers in operations such as brick manufacturing, foundries and hydraulic fracturing. In the various construction projects, most of the employers can limit harmful dust exposure by using equipment that is widely available, even just using water to keep dust from getting into the air would be beneficial and

[1]Silicafume (2018) http://www.silicafume.org/general-silicafume.html.

ventilation system is also helpful to reduce the risk (OSHA 2016). In the construction, due to lack of sustainable restrictions, in many projects, the amount of silica is not monitored and that cause excessive amount of silica use in construction. With an excessive use of silica, human health is under danger. Uncontrolled use of such materials should be limited that will affect the current design procedures.

Materials

Concrete as a material in the industry is a mixture of Portland cement, water, and fine and coarse mineral aggregates, and sometimes various admixtures are also added in most of the cases. When all of the ingredients are mixed in the appropriate proportion, a complex chemical reaction occurs. This reaction is called as 'cement hydration', the process by concrete hardens and cures (Domone and Illston 2010).

In the present study in experimental set up, testing was planned to define the mechanic characteristic through various percentages in the existing design procedure. To investigate the effect of the ingredients in concrete, slag cement and fly ash were used. Slag cement and fly ash are explained below to define the mechanical characteristics of concrete.

Slag Cement

In the past few decades, the use of slag cement in the concrete industry has rapidly increased, since it has been considered an inexpensive material that enhances concrete properties. Before, slag cement was used in concrete industry in Europe. It had been found that the concrete structures made with slag cement show long-term high performance. In addition, using slag cement provides a durable concrete structure, which will reduce life-cycle cost (Slag Cement Association 2002). In addition, slag cement can be used either as supplementary material added to the concrete mix or as a mineral admixture blended with cement during the production of concrete for various constructions. Slag cement consists of silicates, aluminosilicates, and calcium-alumina-silicates (FHWA 2016, Lewis 1981). Slag cement is a non-metallic material that is produced as a waste material in iron production in the blast furnace. At a temperature at around 2732° F (1500° C), the slag is tapped from the blast furnace and is converted into different classifications depending on the cooling method. According to ASTM (C125-00a) "Standard Terminology Relating to Concrete and Concrete Aggregates," there are three typical types of slag cement: (a) Air-cooled blast-furnace slag, (b) Granulated blast-furnace slag, (c) Expanded blast-furnace slag (Lewis 1981).

Fly Ash

This material is a by-product that results from electrical power generations through the industry. Fly ash is basically a residue, carried by the generated gasses away from the burn out while the heavier unburned residue settles down in the furnace. The lighter residue characterized with cementitious properties is used with concrete. For most of the cases, the fly ash contains various percentages of calcium (Thomas 2007). According to ASTM C618-05, there are three types of fly ash: Class N, Class F, and Class C. Both Classes F and C are used in the concrete industry mostly.

Water/Cement Ratio (W/C)

Water content in the concrete mix has a significant impact on the UPV test values. Ye et al. (2001) conducted the UPV test on different concrete samples with different (W/C) ratios, as 0.4, 0.45, and 0.5. They found that samples with lower W/C have higher UPV values comparing to other samples. The explanation of the difference is associated with various reasons, such as higher solid mass for those mixes and lower percentages of capillary pores. It is important to point out that the effect of Water and Cement ratio is almost impossible to understand at the early ages of concrete samples due to the higher amount of capillary pores (Panzera et al. 2011).

The Size of Aggregate Particles

The aggregate particles sizes and contents have a great impact on concrete properties. Therefore, the effect of aggregate should be considered during the UPV test. Higher aggregate sizes and amounts increase the UPV measurements. Also, a decrement in the compressive strength occurs due to the high aggregate amounts (Panzera et al. 2011). To get positive values from both tests, a high amount of attention should be paid during the mix design procedures.

Methodology

Materials generally contain crystalline silica which is not hazardous unless they are disturbed, generating small-sized particles that can get by people. For instance, in construction industry, blasting, cutting, chipping, drilling and grinding materials that contain silica can result in silica dust that is hazardous for people. In cement production, as a result of hydration is thermodynamically stable. Stability comes with high temperature as well. High temperature may create a stable, continuous and dependable environment and therefore, formation turns out a chemical reaction with high demand reactive material.

In addition to material characterization levels, it is also important to note that, hydration at high temperatures leads to the formation of highly crystalline silicate hydrates with more Ca/Si ratio in the reactive material (Alp and Akin 2013, Bouzoubaa and Foo 2005). Type I Portland cements contain less than 0.1 % crystalline silica by weight. In concrete, slag cement has been used either as supplementary material added with the concrete mix or as a mineral admixture blended with the Portland cement during its production (ASTM 2003, 2012).

Based on the site investigations, it is observed that, slag cement consist of silicates, aluminosilicates, and calcium-alumina-silicates (FHWA 2016). By using fly ash in the concrete mix; concrete quality has enhanced and performance has increased. Comparing with the others, fly ash is the light unburned residue that is carried by the generated gasses away from the burning zone while the heavier unburned residue settles down in the bottom of the furnace. In many cases, it has a light characterization and the lighter residue characterized with cementitious properties is used with concrete. Based on the current practices in the construction, applications in construction, and experimental studies conducted in the various lab conditions, Fly ash contains various percentage of calcium (Thomas 2007, Barnett et al. 2006).

In this present paper, to reveal the silica effects on concrete, design setup has been discussed and investigated. By using an experimental design setup, the efficiency of crystalline silica in concrete samples has been investigated. In the experimental setup, various concrete samples were created and used in the research. As given in Figure 1, samples were created by using different Portland cement percentages and in different mixture proportion as detailed in Table 1 and Table 2. Table 1 summarizes the samples for detailing the characterization of the samples. In the research, for the testing process, UPV and Compression test equipment were used to record different percentages (Qasrawi and Marie 2003, Yang et al. 2011).

In the research, to understand the structural and mechanical response of the material, the samples were created based on the protocols. In the testing, components of each mix were weighted using an accurate electronic scale, and were later mixed together with 0.45 Water and Cement ratio using a concrete mixture equipment following the ASTM C192 procedures in Section 7.1.2 for mixing concrete. After finalizing each mix, the concrete cylinders were cast in plastic molds. To prevent the loss of moisture and to start the initial curing process the samples were stored in the room temperature for 24 hours. After the 24 hours, the concrete samples were demolded from the plastic molds and placed in a wider water tank for 28 curing days at a temperature between 70° F (21° C) to 77° F (25° C). With these constraints, materials have been prepared for the experimental investigation.

Table 1. *Prepared Sample Sets used in the Tests*

Mix 1 (Sample A)	Control mix without Slag and Fly ash
Mix 2 (Sample B)	Concrete mix with 50% slag
Mix 3 (Sample C)	Concrete mix with 25% fly ash

Figure 1. *Concrete Samples used in the Testing*

Table 2. *Mixture Proportion of the Concrete Mixes*

Mix Number	W/C	Concrete volume ft^3	Mixture proportion lb/ft^3 (kg/m^2)				
			Cement	Slag cement	Fly ash	Fine aggregate	Coarse aggregate
1	0.45	1	21.43 (343)	0	0	42.85 (686)	85.72 (1,373)
2	0.45	1	10.72 (171.71)	10.72 (171.71)	0	42.85 (686)	85.72 (1,373)
3	0.45	1	16.1 (258)	0	5.36 (85.85)	42.85 (686)	85.72 (1,373)

Experimental Testing

In experimental testing, to determine the effect of crystalline silica on concrete samples, created samples were first put in the water for 28 days. 14 days after, they were removed from the water. In this sequence, samples were investigated by using UPV test as seen in Figure 2a. Afterwards, samples were cracked by using compression equipment up to 50K loading as seen in Figure 2b. After cracking the samples, second UPV test was run. Then, the samples were put under the compression load until they got cracked as seen in Figure 2c. Cracking loads were recorded for the final stage of the research and the results were compared with each other.

Figure 2. *Testing Procedure*

(a) UPV Test (b) Small Crack (c) Crash the Sample

The Ultrasonic Pulse Velocity (UPV) test is a non-destructive test that is used to evaluate the quality of different materials, such as concrete, steel, or wood. Historically, in 1920, the Russian scientist Sokolov was the first to use the UPV test to determine the defects in metal. In the 1940s, the pulse technique was first used on concrete by American scientists through a mechanicly generated pulse. They found that the velocity dependes on the elastic properties of the concrete. Later, electro-acoustic transducers were developed by the Canadian and British, which provided more accurate data (Hannachi and Guetteche 2014, Bungey and Millard 1996). The UPV test is a cost effective test, which can be employed easily and rapidly (Lawson et al. 2011). Test results will be used in the contentious evaluation of the concrete structures during their service life, which minimizes possibility of deficiencies in the concrete and also understand the effect on the concrete material (Lorenzi et al. 2007).

The UPV test essentially consists of an electrical pulse generator, two transducers (transmitting transducer and receiver transducer), calibration bar, and coupling gel (Hannachi, and Guetteche 2014, Bungey and Millard 1996). The gel should be placed between the transducers and the contact surface because "accuracy of transit time measurement can only be assured if good acoustic coupling between the transducer face and concrete surface can be achieved" (Sutan and Meganathan, 2003). The UPV test method is based on measuring the pulse speed and the transit time inside the concrete structures. The speed of waves depends on the elastic properties of the concrete. High-frequency sound waves travel through the concrete by using a transducer, which stays in contact with one of the concrete surface. The longitudinal speed of waves depends on the density of the concrete. A higher density means a faster wave speed.

Figure 3. *Ultrasonic Pulse Velocity Equipment*

The other test carried out in the research is compression test. Compression equipment has been used to test the samples. Concrete strength has been determined for its strength as a structural material. A compression test is a common practice to define the mechanical characteristics of concrete samples. The maximum recorded force in the test through the equipment is the compression strength of that particular sample.

The concrete compression test equipment that was used in this research is CM-2500 series manufactured by Test Mark industries. This equipment has a loading capacity ranging between 2,500-250,000 lbs. (11-1112 kN); it meets with the ASTM C-39 and AASHTO-22 for testing concrete specimens. The machine is controlled by valve and hydraulic pump; the digital reading screen is placed on the right side of the test machine. This equipment has load accuracy ±0.5% and supplied with heavy duty pressure cylinders. The CM-2500 has an auto shutdown when the piston exceeds its maximum stroke. Besides, an electronic safety feature turns the hydraulic pump off at sample failure or when the equipment reaches its maximum capacity. During the specimen test, the rate of loading was determined according to the ASTM-39 standard, which was 37±7 psi (255±48 kPa) per second.

In the research, two main experimental set up were established. In these two experiments, samples were tested. Followed experimental steps are given in Table 3. Procedure is followed according to literature review (Bungey and Millard 1996, Wang et al. 2006, Ye et al. 2001). Samples were placed in a water tank for curing for 28 days. The UPV test was performed on each specimen following the ASTM C597-02 Standards for three different positions on cylinders' axial direction; the specimens were subjected to (2.0 MHz) sound waves during the test. The benefit of documenting the UPV values at the beginning was to indicate the initial pulse velocity value, which gives an idea about the status of the concrete cylinders' structure before applying any compression load. In addition, these values were used as base values during the evaluating process of the self-healing capability and in calculating the damage level for each cylinder. Right after measuring the initial UPV value, a compression load was applied on concrete cylinders approximately 50,000 lb. (1,500 Psi) [10.34 Mpa]. The point of this step was not to measure the ultimate compressive strength of the specimens but to force each sample to generate internal cracks within its structure. On the same day, the UPV test was performed again for the all samples to measure the changes in pulse velocity values in comparison with the measured initial values. There were some changes in UPV, which indicated that the specimen structures were damaged due to the load application. Then, the saturated samples were placed back in the water tank, while the frozen samples were returned to the freezer for 30 days. At this point, the first stage of the testing procedures was completed.

After the 30 days, the second stage was started, which was to remove the samples from the water and freezer to perform the next UPV test. Then, the samples were placed back in water and freezer for another 30 days. After 60 days from the first pulse velocity evaluation, the final UPV test was executed for all concrete samples. The purpose of applying the UPV test in different periods was to build a relationship between the healing degree and rate with time for each concrete mix. At the end of the experiential investigation, the samples were crushed by using the compression testing equipment by applying an axial compression load until the failure point.

Table 3. *Experimental Steps*

Steps	Action
1	Poured concrete into molds
2	After waiting 48 hours, put in water for 28 days
3	Removed from water to dry for 14 days
4	Run the UPV test for the first time: calculating the time and velocity (10 tests for each sample).
5	Create small crack inside samples up to 50K loading
6	Run the UPV test for the second time.
7	Put the sample under the compression load until it crashed.

Research Findings

In the present research, samples were tested by using the Ultrasonic Pulse Velocity (UPV) test and Compression Test equipment to investigate to increase the strength of concrete. As a result, UPV test and compression test results are given in charts for comparison. Figure 4 gives the comparison of compression test results. Table 4 gives the UPV test results. Two different sets of UPV tests results are summarized. These results were recorded with the same order of experimental steps as given in Figure 5.

Figure 4. *Compression Test Results*

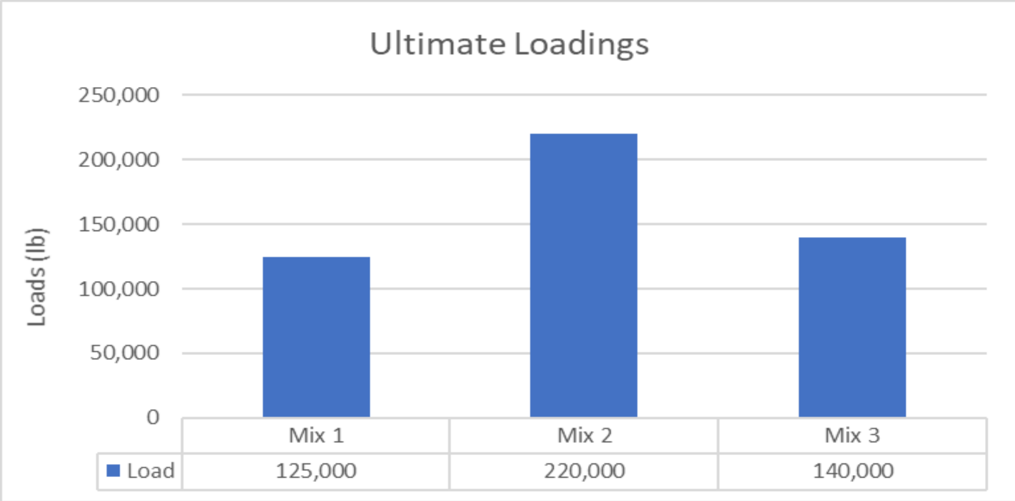
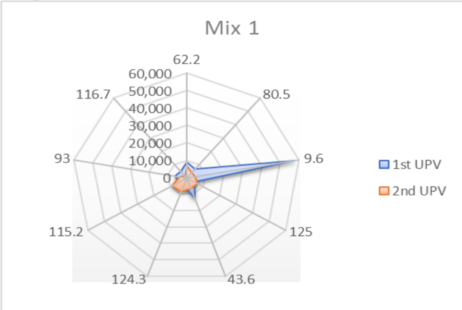
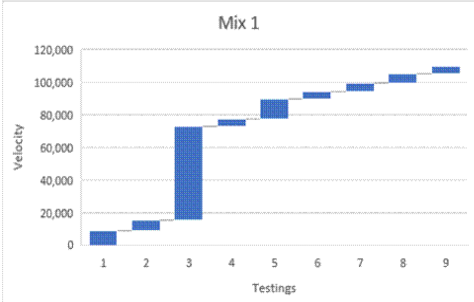


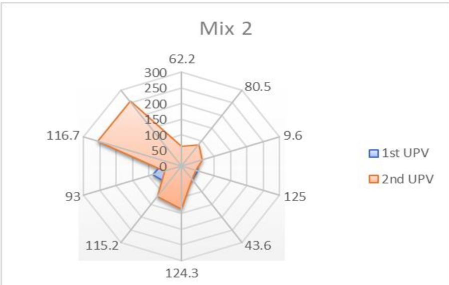
Figure 5. *UPV Test Results*



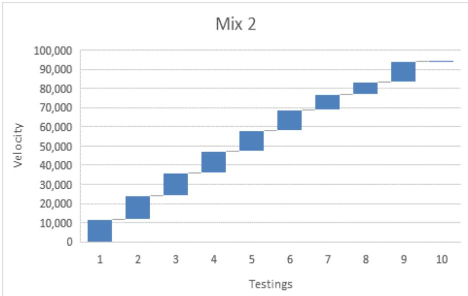
a) Mix 1 UPV Distribution



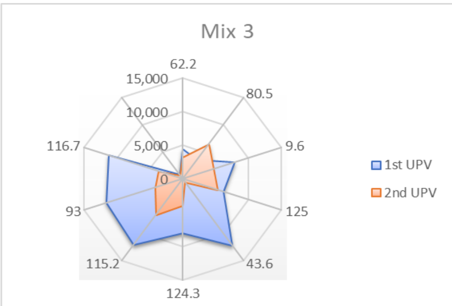
a) Mix 1 UPV Test Results



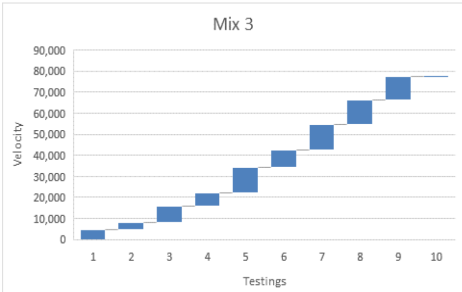
b) Mix 2 UPV Distribution



b) Mix 2 UPV Test Results



c) Mix 3 UPV Distribution



c) Mix 3 UPV Test Results

Table 4. *UPV Test Results*

	Mix 1	1st UPV	Mix 1	2nd UPV
	TIME	**VELOCITY**	**TIME**	**VELOCITY**
Mix 1	62	8,842	81	6,740
	80	6,832	137	3,994
	9	57,292	125	4,404
	125	4,416	85	6,433
	43	12,557	82	6,651
	124	4,425	66	8,271
	115	4,774	63	8,648
	93	5,926	154	3,560
	116	4,712	474	1,158
	Mix 2	**1st UPV**	**Mix 2**	**2nd UPV**
	TIME	**VELOCITY**	**TIME**	**VELOCITY**
Mix 2	46	11,752	62	8,748
	45	12,222	83	6,555
	46	11,905	63	8,703
	48	11,364	44	12,443
	52	10,577	52	10,577
	49	11,066	136	4,041
	68	8,076	119	4,591
	87	6,271	51	10,618
	51	10,597	256	2,142
	67	819	256	2,151
	Mix 3	**1st UPV**	**Mix 3**	**2nd UPV**
	TIME	**VELOCITY**	**TIME**	**VELOCITY**
Mix 3	122	4,508	176	3,125
	159	3,448	86	6,373
	69	7,902	117	4,677
	88	6,201	102	5,345
	45	12,222	922	596
	68	8,088	135	4,065
	45	12,141	83	6,611
	47	11,579	130	4,211
	48	11,247	148	3,699
	768	715	909	605

Different mixes were given and time vs velocity values are indicated in Table 4 for two sets of UPV tests. According to the results, mix 2 values are higher comparing to mix 1 and mix 3. Mix 1 and mix 3 values are closed to each other. Mix 2 has slag in the mix. In mix 3, there is fly ash in the mixture. Both of them have similar silica percentages in the mixture. Therefore, it can be seen through this research, strength is not selective parameter for silica fume percentage in the concrete.

Conclusions

The present paper investigates impacts of crystalline silica in concrete by changing concrete mixture proportions through mechanical properties. Effects of crystalline silica on different cementitious and polymeric materials, such as slag cement and fly ash have been investigated and obtained results are given. The research methodology consisted of two different experimental tests as, the ultrasonic pulse velocity (UPV) and compression test. As seen in Figure 4, resistance of Mix 2 is the highest with 220,000lb ultimate loading. Mix 3 and Mix 1 are at similar ranges. Based on these results, Mix 2 values are the ones that can be used in the mix design procedure with their higher values. The UPV test results were given in Figure 5. According to results from UPV and compression tests, Mix 2 has higher values.

Based on the investigation carried out through the research, Silica affects the concrete behavior. With existing design procedures and protocols, silica use is at an excessive level and should be controlled in the upcoming regulations. With the new restrictions by OSHA, it is obvious that the silica use will be limited in the concrete. Therefore, it is important to investigate the structural and mechanic characteristics for concrete using different ingredients and additives. With different material use, characteristics of concrete will be different.

With increased health concerns and awareness in the wider spectrum in recent years, industrial byproducts become critical to understand in concrete and its applications. One such by-product is silica, which is a byproduct of the silicon and ferrosilicon industry. Silica is one of the main and critical materials used in high strength high performance concrete production and its derivatives. In recent years, there have been various research work completed to cover this issue in the existing frame. Some of Department of Transportations (DOT)'s started working on evaluating effects of silica in concrete in physical, chemical properties of it, and its reaction and resistance mechanism.

Even it is still controversial, crystalline silica has a possible cause of lung cancer or some other diseases and therefore, it is important to limit the use of silica in the concrete industry. Millions are interested in this decision. In a short run, it is important to define the effects of silica in strength and characteristics. That will be extended in the long run. Department of Transportations (DOT)'s will change or revise their design procedures. With OSHA's new regulation, in construction industry, a game changing regulation will be effective in next years. To make right decisions in the concrete design, it is important to get accurate data and definitions for concrete characteristics.

Figure 4 gives the comparison of compression test results. Within the results, Mix 2 has the highest value. With the strength characteristics of concrete samples, the max strength values were determined. In Figure 5, UPV test values are given below. For each mix, UPV change was sketched for three different cases. The coverage and change are given in the diagrams. Characteristic definition can be based on these charts and it would be possible to see the change with different design procedures. Distribution gives the core part for the stress distribution in two different areas. So, the main areas for a stress distribution are demonstrated in Figure 4. In the chart, the change is given with the change in the UPV value changes. In addition to the graphs, Table 4 is summarizing the UPV test results with their values for three different mix set up.

This research is representing the results of the carried out experiments. The sample number should be increased and the results should be increased with more samples and more alternatives. Various types of concrete ingredients should be included to the result to give better coverage in the design procedures.

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Influence of Penstock Outlet, Number of V-Blades, Flat Blade Lateral Twist Angle and Hub to Blade Ratio on the Performance of a Simplified Pico Hydropower System

By Alex Okibe Edeoja[*], Matthew Ekoja[†] & Taofeek A. Yusuf[‡]

A study to determine the influence of penstock outlet, number of v-blades, flat blade lateral twist angle and the hub to blade ratio on the performance of the Pico-hydro system has been conducted. Five turbine runners with 8, 9, 10, 11 and 12 v-blades were fabricated and tested on an already existing system. A runner with adjustable flat blades was also fabricated and tested for twist angles of 50^0, 55^0, 60^0, 75^0 and 90^0. Runners with v-blades but having hub to blade ratios of 0.3, 0.4, 0.55, 0.65 and 0.7 were also tested. The turbine was connected to 3.9 kVA alternator via a v-belt drive and a 1 Hp pump was used to sustain the flow. The turbine and alternator shaft speeds were measured, and the level of water in the overhead and underground reservoirs monitored. The flow rate, available head and the hydraulic power were computed for each operation. The results obtained indicated that using a combination of a runner with 12 blades and a penstock outlet of 20 mm, 0.55 hub to blade ratio and lateral twist angles greater than 75° combined with penstock outlets larger than 20 mm have the potentials of better performance in terms of power generation. The results of correlation and reliability test using Cronbach's alpha carried out on the data at 95% confirmed these findings. This will be very useful for further development of the system in order to attain implementable status as a clean and decentralized energy source.

Keywords: Blade Lateral Twist Angle, Hub to Blade Ratio, Number of Blades, Pico Hydro, Penstock Outlet.

Introduction

The challenge of the 21st century is how to develop sustainably and maintain the quality of life for a growing population with higher expectations for wellbeing. Underlying this challenge is the need for sufficient and sustainable supplies of energy to provide the economic activity underpinning these expectations. The measure of development in any society is synonymous with the level of energy consumption (British Petroleum 2017, Newell and Phillips 2016, SEP 2013, ECA 2014, Edeoja et al. 2015a). Energy plays the most vital role in the economic growth, progress, and development, as well as poverty eradication and security of any nation. Uninterrupted energy supply is a vital issue for all countries today (Obande et al. 2017, Arto et al. 2016, Lajqi et al. 2016, MDGs 2015, UNDESA 2014). Future economic growth crucially depends on the long term availability of

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energy from sources that are sustainable, affordable, accessible, and environmentally friendly. It is noted that the standard of living of a given country can be directly related to the per capita energy consumption, as the per capita energy consumption is a measure of the per capita income as well as a measure of the prosperity of a nation (Lipu et al. 2017, Shittu 2015, WHO 2015, Portale and de Wit 2014, Bergasse et al. 2013, Saatci and Dumrul 2013, Pirlogea and Cicea 2012, Lior 2010).

World Energy Council (2013) addressed the main factors that have influenced the development of the global energy sector the most over the previous two decades adding that the world has changed significantly in this period. The council summarized the principal drivers that have shaped energy supply and use to include sharp increase in the price of oil since 2001, financial crisis and slow economic growth with drastic reduction in energy consumption in large economies, shale gas in North America, the Fukushima Daiichi nuclear accident and the volatile political situation in the energy supplying countries in the Middle East and North Africa. Others are lack of global agreement on climate change mitigation, collapse of CO_2 prices in the European Emissions Trading System, exponential growth in renewables, deployment of 'smart' technologies, energy efficiency potential still remaining untapped, and growing public concern about new infrastructure projects, including energy projects (Samy 2017, Hossain et al. 2017, Choi et al. 2017).

Currently, the global energy demand is rising fast as population and emerging economies like China and India are growing exponentially with small and medium enterprises springing up. In developing countries of Africa like Nigeria, the International Energy Agency forecasts that energy demand would be 50% higher in 2030 than they are today (British Petroleum 2017, British Petroleum 2016, UNIDO, 2010, Sambo 2008a, Sambo 2008b, IEA 2007). Yet fossil fuels on which the world mostly depends are finite and are not environmentally friendly (Akuru and Okoro 2011, Williams and Alhaji 2003). There is therefore a gradually shifting of attention to potential renewable energy resources for power generation like wind, solar and hydro power resources. Renewable energy constitutes about 15% of the world's energy mix with hydropower making most of it (REN21 2016, UNFCCC 2015, REN21 2014, Bala 2013a, Bala 2013b, UNIDO 2009).

Access to electricity is a prime key to development as it provides light, heat and power for productive uses and communication, and the global demand keeps growing. A vast majority of the people in developing countries, especially in rural areas, do not have access to electricity (IEA 2015, Shezi 2015, Yuksel et al. 2013, Sambo 2005). This number keeps increasing despite the rural electrification programs because they are not sufficient to cope with the population growth or the political will in some of the places is not strong enough or absent (Omprasad 2016, Ramos et al. 2012, Adejumobi et al. 2013, Wang 2009). Moreover, despite the fact that about 80% of the world's population lives in developing countries, they consume only about 20% of the global commercial energy. According to the World Bank, most of the world's poor people spend more than 12% of their total income on energy, which is much more than what a middle-income family in the developed world spends (World Bank 2008, World Bank 2006).

Studies have indicated that about 40% Nigerian households have access to the national grid with more than 45% not having access to any form of electricity. About 6% have supported their access to the grid with standby generators and more than 3% completely relied on them. Also, about 1.1% of households have access to the rural electrification programs while a vast majority of Nigerians still use firewood for cooking with about 20% relying on kerosene. This is a direct consequence of low access to and low reliability of electricity services. These findings show the urgent need for efforts for further developments of the overall Nigerian electricity sector as well as rural electrification programs to ensure rapid economic development (Edomah 2016, Adejumobi et al. 2013, Oseni et al. 2012, Sambo 2008c). There is a need to revolutionize the way energy is produced and used to reduce these impacts while providing energy services to the billions of people who have inadequate or no access to electricity (Shezi 2015, Mustonen et al. 2010). Population growth makes the challenge even harder. The energy revolution will require moving from electricity systems based on large-scale fossil fuels, large hydro and nuclear fission plants to the ones based on new renewable sources and massive improvements in the efficiency of production, transportation, and storage and use of energy (Kumar and Biswas 2017, Okonkwo et al. 2017, Paun and Paun 2017, Ribal et al. 2017, Nguyen et al. 2016).

Water is the better choice among renewable sources because a small-scale hydropower is a relatively very cost-effective and reliable energy technology to be considered for providing clean electricity generation (Liu et al. 2013a, Liu et al. 2013b). Hydropower is a renewable, economical, non-polluting and environm-entally benign. It accounts for about 19% of global electricity production from both large and small power plant second only to fossil fuels (Adamkowski 2012, Gatte and Kadhim 2012, Mishra et al. 2011a, Mishra et al. 2011b). The world has endless potential for hydropower generation. A lot of hydropower stations have been built all over the world and many more projects with a capacity above 100, 000 MW currently going on globally. Asia has the largest contribution of around 84, 000 MW (Nikolaisen 2015, Kaunda et al. 2012). In Nigeria, the potential is about 14,750 MW of power. About 1980 MW of this potential has been explored at Kainji, Jebba and Shiroro hydropower stations, leaving 12,200 MW unexplored (Bala 2013b, Adejumobi et al. 2013, Ohunakin et al. 2011, Olusegun et al. 2010). This implies that only about 14% of the nation's hydropower potential is in use. This inability to exploit its vast hydropower potential and to the fact that the available large hydropower plants are not operating up to installed capacity has negatively impacted power supply in Nigeria (Olukanmi and Salami 2012, Akuru and Okoro 2011). The present government has resuscitated interest in developing the project at Mambilla plateau in a bid to tackle part of the power supply problem.

Hydroelectric power plants despite having many advantages over other energy sources, have potentially negative environmental and socio-economic impacts (Nikolaisen 2015, Finardi and Suzzanto 2013, Hussey and Pittock 2012, Islar 2012). It is not a reliable source of energy because it depends on the hydrological cycle. Also, global climate change will increase rainfall variability and unpredictability, translating to more unpredictability, and increased flooding due to global warming is a big hazard to the safety of dams (Cunbin et al. 2012, Jia-kun 2012, Jager 2008). Furthermore, reservoirs lose storage capacity to sedimentation which can diminish the capacity of dams to generate power. Hydropower projects also alter the habitats of aquatic organisms and affect them directly (Baumann and Stevanella 2012, Deng et al. 2012, Deng et al. 2011, Liu et al. 2012, Fjeldstad et al. 2012, Horlacher et al. 2012). Millions of people have been relocated from their homes to make way for dams, losing their land, livelihoods and access to natural resources and enduring irreparable harm to their cultures and communities (Melikoglu 2013, Bohlen and Lewis 2009). There is also growing evidence suggesting that reservoirs emit significant quantities of greenhouse gases especially in the lowland tropics (Chanudet et al. 2012, Cheng et al. 2012, Amor et al. 2011, Liu et al. 2011, Miller et al. 2011). Also, hydropower is often falsely promoted as cheap and reliable, projects are prone to cost overruns and often do not produce as much power as predicted (Aslani 2013, Goodland 2010, Sternberg 2010). The foregoing demerits are more directly applicable to large hydropower schemes which inform the need to resort to smaller schemes (mini, micro and Pico). They have continued to gain increasing popularity especially in remote areas due to design simplicity, ease of operation and relatively low environmental impacts (Wohlgemuth 2014, Pascale et al. 2011). Furthermore, communities could take advantage of simple drinking water projects or irrigation systems to install small hydro schemes.

Pico-hydro power provides a very good option for applying the advantages of hydropower while minimizing the operational and natural shortcomings. It suits the general requirements of smarter, smaller and decentralized systems, generating up to 5 kW. It has become a very useful option in Asian developing countries where the topography inhibits the uptake of more conventional grid-connected energy systems (Nimje and Dhanjode 2015, Xuhe et al. 2014, Haidar et al. 2012, Alexander et al. 2009a, Alexander et al. 2009b, Chuenchooklin 2006, Maher et al. 2003). Over the last 30 years it has been proven as a cost effective, clean and reliable method of generating electricity and mechanical power for off-grid applications and will play an important role in rural electrification into the foreseeable future. In Nepal, as at 2013, about 300 Pico hydro schemes constructed by Practical Action are producing electricity while 900 others are used for mechanical power only (Cobb and Sharp 2013).

There are many sites suitable for Pico hydro development in Nigeria as in many other African countries. Pico hydro has made some in roads in sub Saharan Africa as well, where electrification rates are some of the world's lowest (Wang 2009). However, focus has not been given to it as part of frantic efforts to combat the energy crisis (Bala 2013b, Ajuwape and Ismail 2011). This could be most likely as a result the desire in developing countries for executing gigantic projects which most often become moribund. If fully utilized, it would contribute remarkably to reducing the energy problems of domestic and commercial consumers in addition to providing a cheap source of power to remote areas where the extension of grid system is comparatively uneconomical (Adejumobi et al. 2013, Cobb 2011, Olusegun et al. 2010).

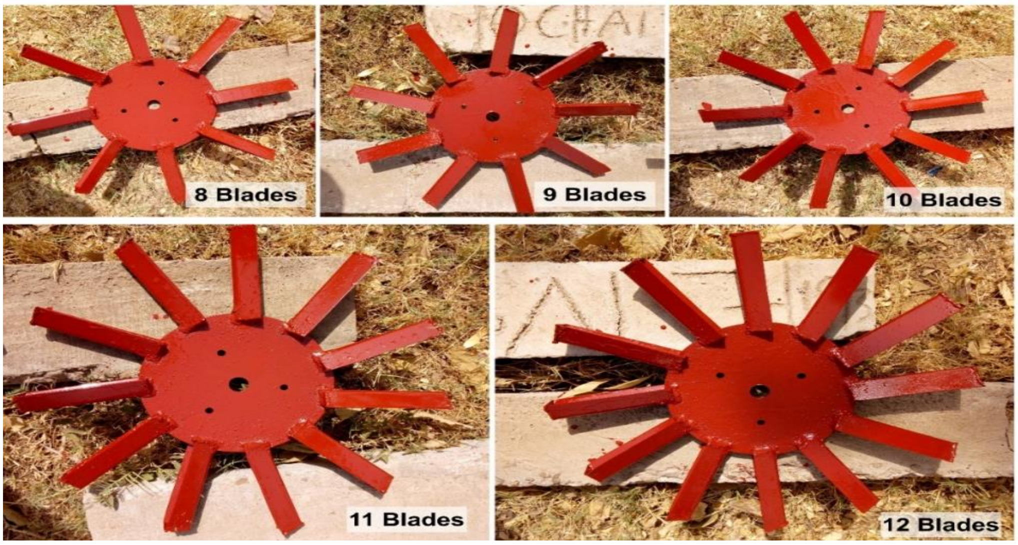
Pico hydro systems are not prone to sabotage and terrorist attacks as individuals and communities take responsibility of safeguarding their own facilities. Due to the increased rate of terrorist activity in the country, the need and use for small Pico hydro is more attractive as power can be generated within the domestic environment, hence increasing energy security since generation and distribution are simplified (Othman et al. 2015, Alexander and Giddens 2008a, Alexander and Giddens 2008b, Williams 2007). While presenting significant advantages, its implementation has several challenges including a heavy dependence on site specific conditions for scheme design. Moreover, seasonal fluctuations of water levels also affect the operation of the conventional Pico hydro schemes, and low water levels do not allow optimal operation while very high ones can sweep the units away (Lahimer et al. 2012). Off the shelf systems have been designed to reduce the site specific requirement but the need for technical expertise and periodic maintenance still remains (Alexander and Giddens 2008a, Maher 2002a, Maher 2002b, Maher and Smith 2001). To further reduce the cost of the technology standard pumps and induction motors could be used in place of conventional generators and turbines (Smith and Williams 2003).

This study however focuses on the investigation of the effect of penstock outlet, turbine blade to hub ratio, the number of V-blades and the lateral twist angle of flat blades on the performance of a simplified Pico hydropower system that has been undergoing development in the Department of Mechanical Engineering, University of Agriculture, Makurdi, Nigeria, for about four years now (Edeoja and Awuniji 2017, Edeoja et al. 2017, Ipilakyaa et al. 2017, Edeoja et al. 2016a, 2016b, 2016c, 2015b). It basically involves an overhead water reservoir with a locally fabricated turbine at its foot and has an underground reservoir. A pump is used for recycling the water, PVC pressure pipes as penstocks, tapered pipes as penstock outlets and an alternator. The present development will explore all the merits of Pico hydro systems while giving control to the user and as result minimize exposure to sabotage as well as bringing the benefits of hydropower to locations without natural water sources for conventional schemes. This particular aspect will further strengthen the prospects of eventually implementing this system for the end user small energy needs.

Methodology

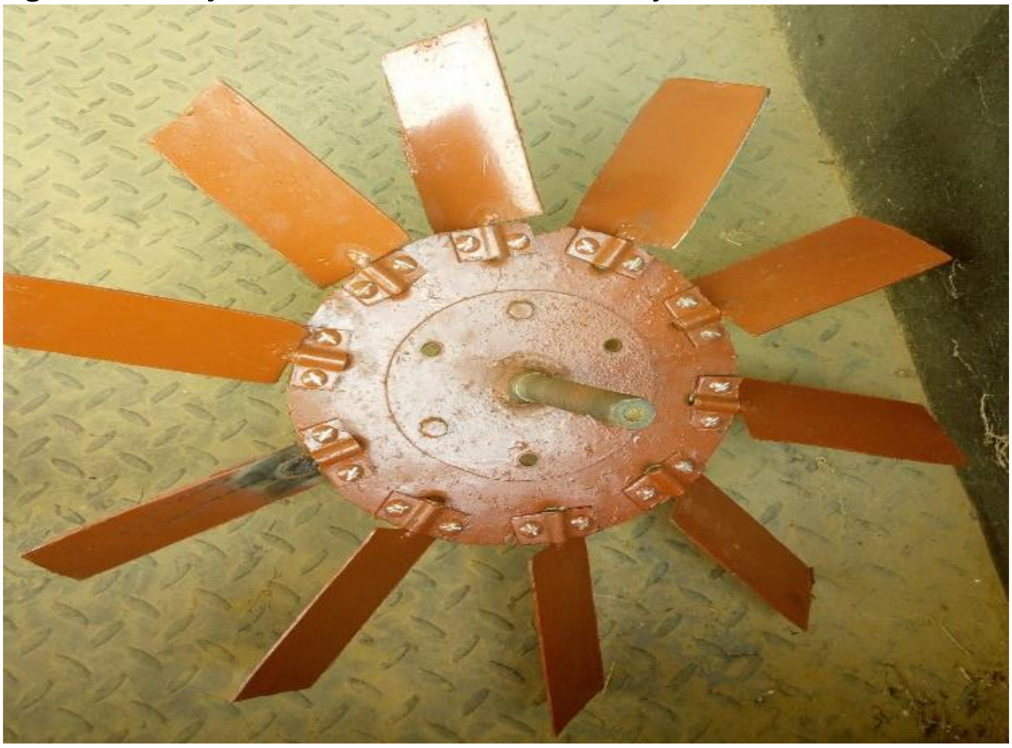
The fabrication of the basic components of the system was done in the Mechanical Engineering workshop of the Federal University of Agriculture, Makurdi, Nigeria. Three parameters, number of v-blades, flat blade lateral twist angle and hub to blade ratio were studied with varying penstock outlets as part of an ongoing work. The runner with v-blades comprised of a circular hub with blades welded around its periphery. The diameter of the runners as well as the hub to blade ratio was obtained from Edeoja et al. (2015b). All the hubs and blades were fabricated from a 2 mm and 1.5 mm thickness mild steel sheet respectively. Five sets of runners were fabricated with 8, 9, 10, 11 and 12 blades. The runner assemblies are shown in Figure 1.

Figure 1. *The Runner Assemblies with the Different Number of Blades*



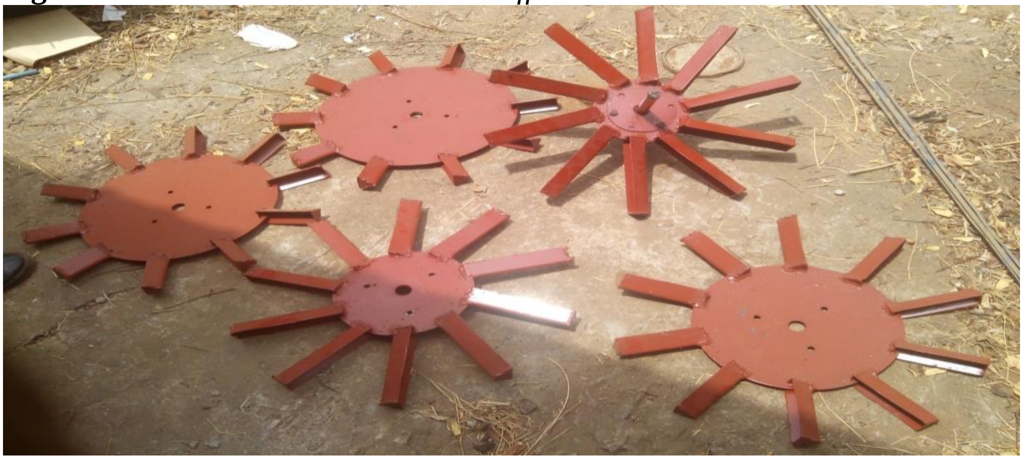
The runner with flat blades had a circular hub of diameter also taken from Edeoja et al. (2015b) with 10 blades equally spaced around its periphery. The blades were detachable from the hub to enable adjustment laterally so that the test can be carried out at different blade angles. The runner with the adjustable flat blades is shown in Figure 2.

Figure 2. *The Adjustable Flat Blade Runner Assembly*



The runner with varying hub to blade ratios also had 10 v-blades based on the recommendations of Edeoja et al. (2016c). Five runners were fabricated with varying length of blades and sizes of hub attached to them. The hub to blade ratios of 0.7, 0.65, 055, 0.4 and 0.3 were selected around the approximate value of 0.55 reported in literature. Figure 3 shows the fabricated runners with the different hub to blade ratios.

Figure 3. *The Runner Assemblies with Different Hub to Blade Ratios*



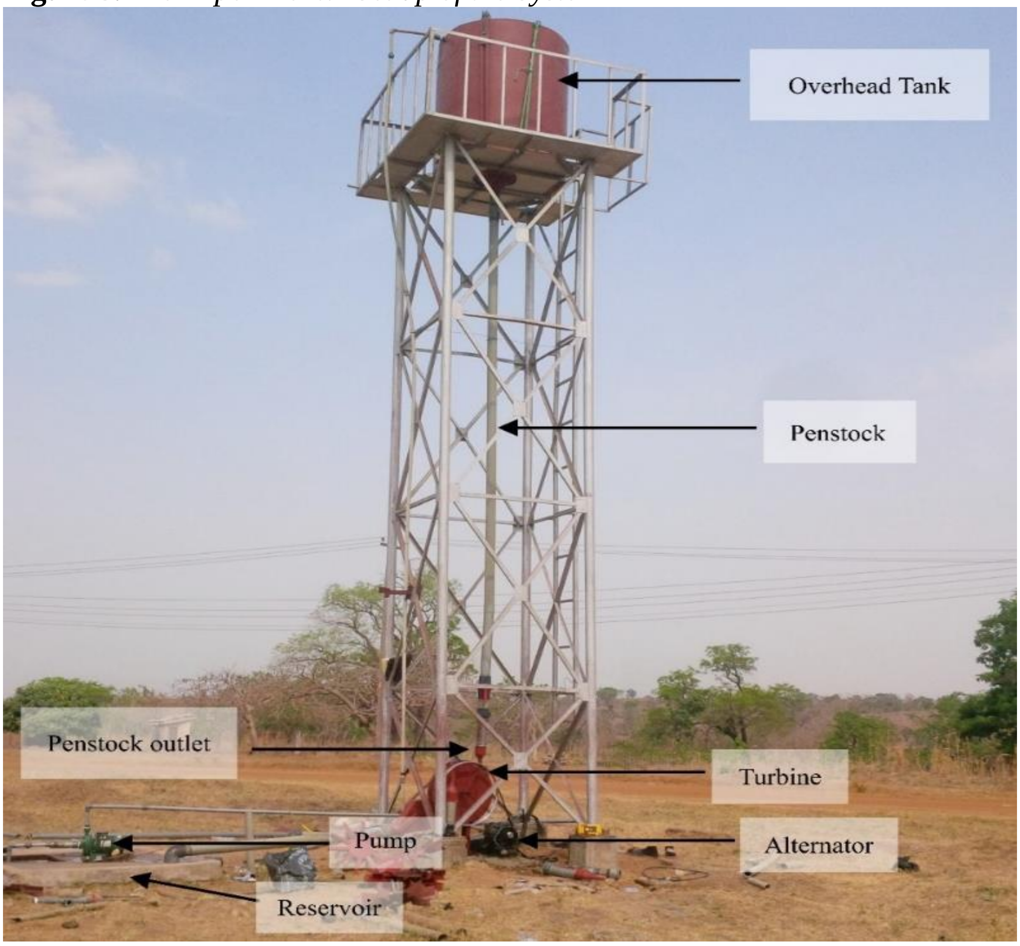
The penstock outlets used were obtained by reducing 76.2 mm diameter to 15, 17.5, 20, 22.5 and 25 mm. The choice of 76.2 mm and reduction to the diameters selected was based on previous aspects of this work reported by (Edeoja and Awuniji 2017, Ipilakyaa et al. 2017, Edeoja et al. 2016a). The penstock outlets used for the study are shown in Figure 4.

Figure 4. *The Penstock Outlets used for the Study*

Each of the runners was clamped to the shaft flange with four M10 bolts and mounted in between two bearings and seals on the already existing turbine casing and covered to allow free spinning of the shaft and prevent leakages from the turbine one after the other. Some grease was also applied to the bearings to reduce friction. The turbine cover was then secured in place with M14 and M13 bolts and the turbine pulley of about 605 mm diameter mounted on the 20 mm shaft. The upper and lower ends of the 76.2 mm PVC penstock were then connected to the overhead tank and the outlet respectively. Care was taken to align the turbine runner, casing and the penstock outlet so as to ensure a good clearance of about 15 mm. The turbine was then coupled to a 3.9 kVA alternator by means of a toothed v-belt drive onto a 50 mm pulley mounted on the shaft in a ratio of about 12:1.

The experimental set up for this study consists of a 1 Hp, 3-10.8 m^3/h pump and the locally fabricated turbine connected in a closed loop with PVC piping as penstock, a 2000 litres overhead tank and a 3000 litres underground reservoir. Figure 5 shows a picture of the entire system.

Figure 5. *The Experimental Set up of the System*



The suction pipe of the pump draws water from the underground reservoir to the overhead tank to create a head. Water is then released from the overhead tank through the penstock and flows through the reduced diameter penstock outlet before impinging on the blades. The flow through the turbine is regulated using a gate valve installed before entry to the penstock. The water jet strikes the blades which are attached to the hub, therefore transferring its kinetic energy to the shaft causing the rotary motion of the hub and the shaft assembly which develops a torque. The torque is then transferred to the alternator.

The experimentation was carried out in three batches. First, each number of v-blades was tested for each of the penstock outlets. Next, five lateral twist angles of the flat blades of 50, 55, 60, 75 and 90° were tested against the various penstock outlets. Finally, the runners with varying hub to blade ratio were then tested. For each test, water released by opening the gate valve through the penstock impinges on the blades. The blades are pushed tangentially by the falling water. The thrust produced by the water on the blades produces a torque on the shaft resulting in revolution of the runner. For each, a DT-2268 contact type tachometer was used to measure the rotational speeds of the turbine and alternator shaft speed in revolutions per minute. Also, the water levels in the reservoir and overhead tank before and after each test were monitored with the aid of a calibrated dip stick and each operation was timed using a stopwatch. The difference in water levels for the overhead tank was used to compute the flow rate. The water level in the overhead tank before the flow is used in computing the gross head. The major and minor losses were also computed. The hydraulic power was computed using the rotational speed of the turbine shaft. The results obtained were then correlated at 95% and a reliability test performed on them using Cronbach's alpha (CA).

Results

Figures 6 to 8 show the variation of the alternator shaft speed with number of v-blades, angle of twist of flat blades and hub to blade ratio respectively obtained for the respective penstock outlet diameters. Figures 9 to 11 show the variation of the alternator shaft speed with the penstock outlet diameter for the three other parameters.

Figures 12 to 14 show the variation of the system computed power with number v-blades, angle of twist of flat blades and hub to blade ratio respectively for the penstock outlet diameters. Figures 15 to 17 show the variation of the computed power with penstock outlet diameters for the three parameters.

Figure 6. *Variation of Alternator Shaft Speed with Number of Blades for the Penstock Outlet Diameters*

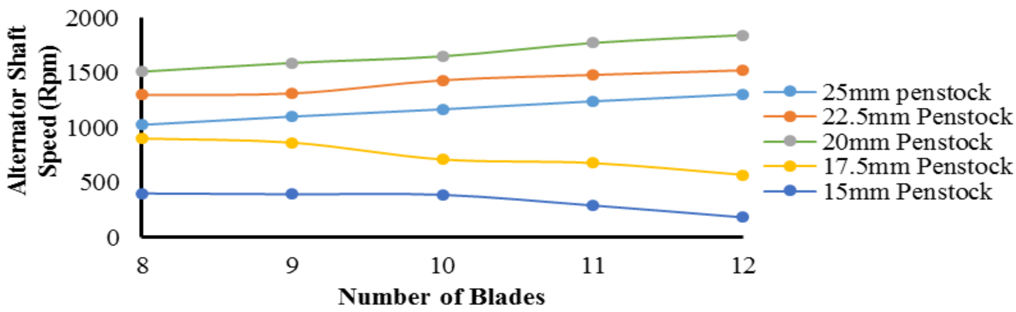


Figure 7. *Variation of Alternator Shaft Speed with Blade Lateral Twist Angle*

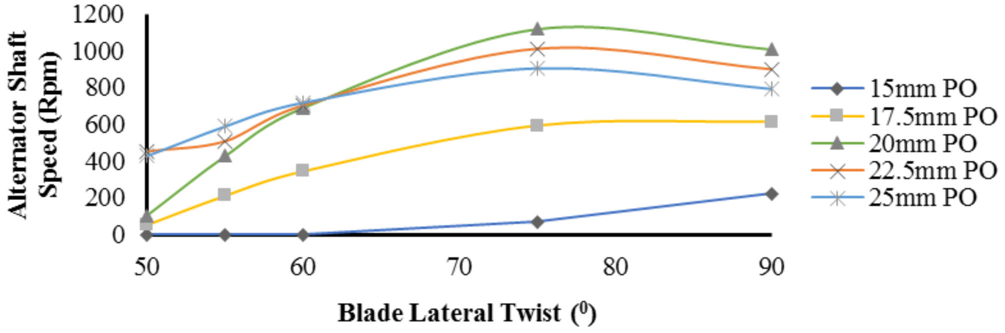


Figure 8. *Variation of Alternator Shaft Speed with Turbine Hub to Blade Ratio*

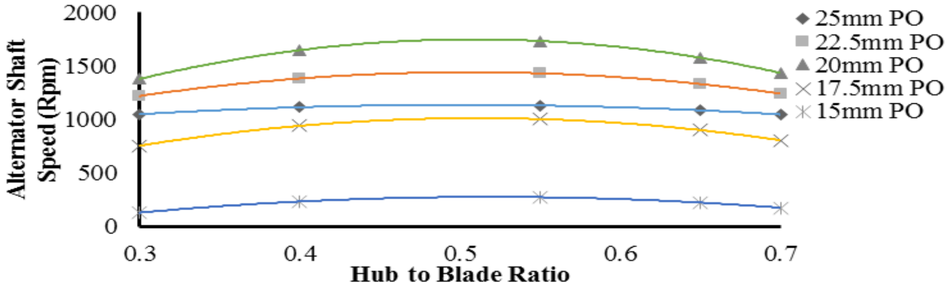


Figure 9. *Variation of Alternator Shaft Speed with the Penstock Outlet Diameters for the Various Number of Blades*

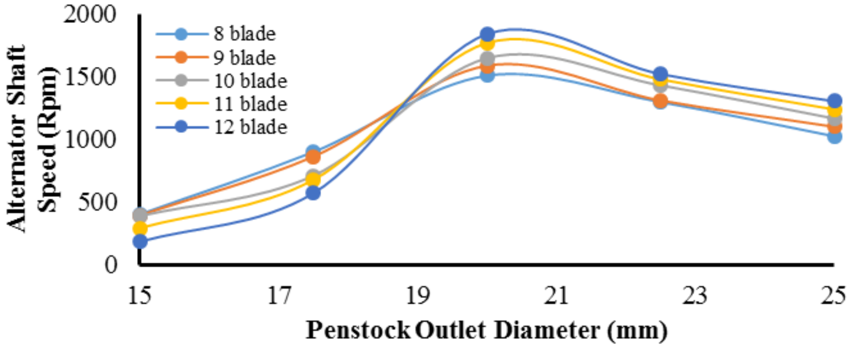


Figure 10. *Variation of Alternator Shaft Speed with Penstock Outlet Diameters*

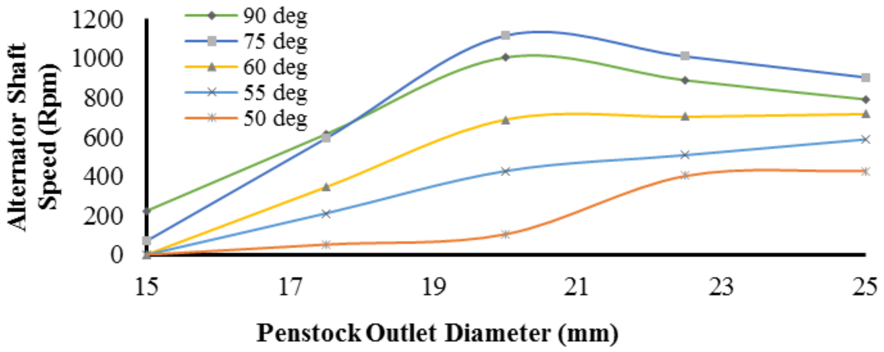


Figure 11. *Variation of Alternator Shaft Speed with Penstock Outlet Diameter*

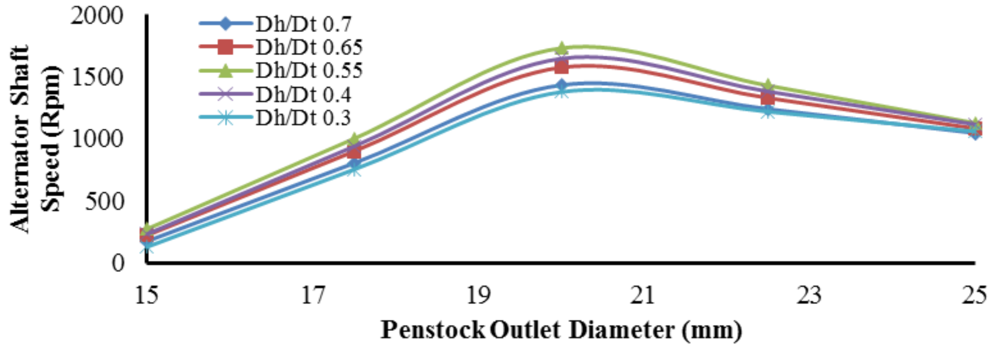


Figure 12. *Variation of Computed Power with the Number of Blades for the Penstock Outlet Diameters*

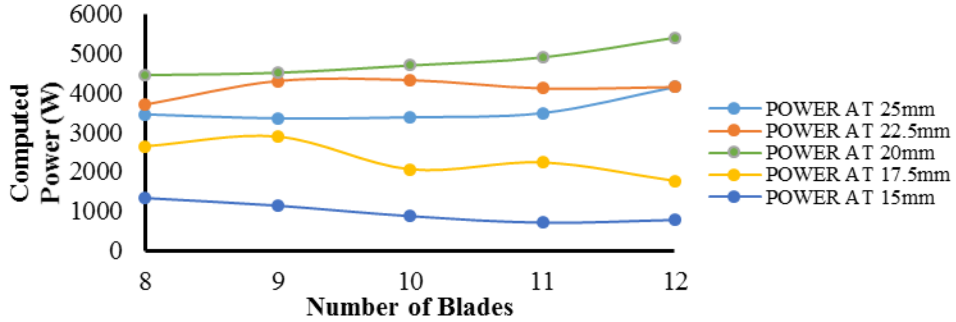


Figure 13. *Variation of Computed Power against Blade Lateral Twist Angle*

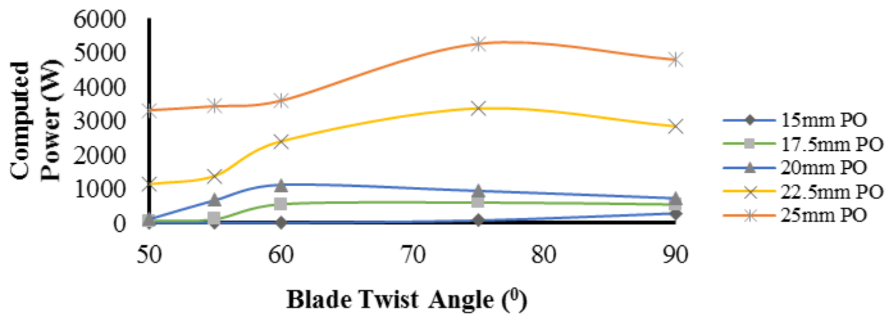


Figure 14. *Variation of Computed Power with Turbine Hub to Blade Ratio*

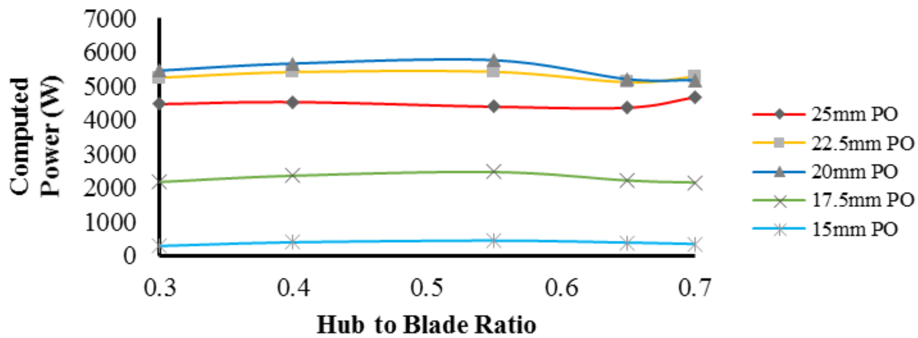


Figure 15. *Variation of Computed Power with the Penstock Outlet Diameter for the Number of Blades*

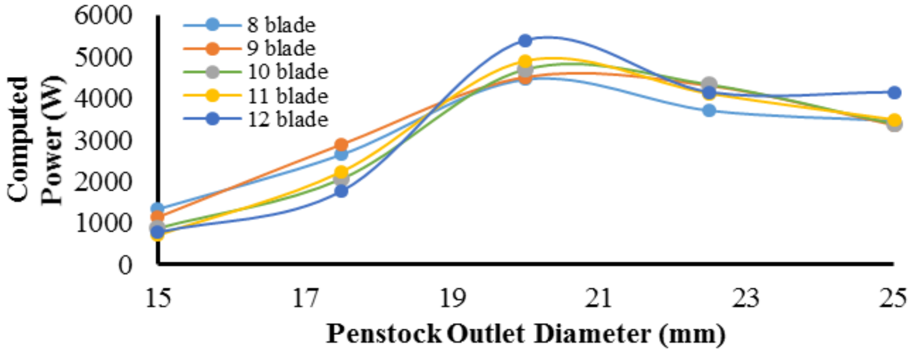


Figure 16. *Variation of Computed Power with Penstock Outlet Diameter for the Blade Lateral Twist Angles*

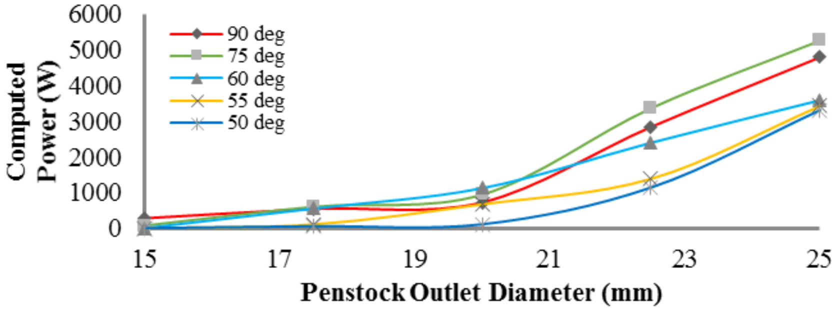
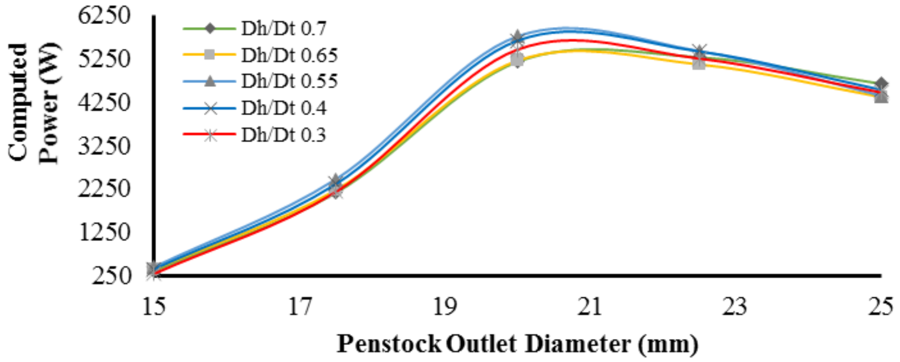


Figure 17. *Variation of Computed Power with Penstock Outlet Diameter for the Hub to Blade Ratios*



Tables 1 and 2 show the summary of the result of Pearson's correlation test carried out on the data, while Tables 3 to 5 show the summary of the result of the reliability tests carried out on the data using Cronbach's Alpha (*CA*). In the tables, apart from the abbreviations already encountered, N_T refers to the turbine shaft rotational speed, *N* the ideal or expected speed of the alternator shaft, % loss the percentage difference between the actual and ideal alternator shaft speeds and *P* the computed power.

Table 1. *P-Value of Relationship between the Parameters and Power*

Parameters	N	P (W)*
BHR	25	0.941
BTA	25	(-)0.263
NOB	25	0.958
N_T (Rpm)	75	0.000
N_A (Rpm)	75	0.000
N (Rpm)	75	0.000
% loss	75	(-)0.133

*(-) indicates negative correlation.

Table 2. *P-Value of Relationship between the Pairs of Parameters*

Parameters	N	N_T (Rpm)	N_A (Rpm)	N (Rpm)	% loss	P (W)
POD	75	0.000	0.000	0.000	(-)0.228	0.000
BHR	25	(-)0.916	(-)0.973	(-)0.827	0.861	0.941
BTA	25	(-)0.005	(-)0.004	(-)0.005	(-)0.152	(-)0.263
NOB	25	0.822	0.831	0.822	0.423	0.958
% loss	75	(-)0.345	(-)0.006	(-)0.781	-	(-)0.133

Table 3. *Reliability of the System on the Number of Blades (NOB) and Other Parameters*

Item	Cronbach's Alpha	CA if Item Deleted
P (W)	0.692	0.662
N_A (rpm)		0.499
N (Rpm)		0.501
% loss		0.724
N_T (rpm)		0.703
NOB		0.721

Table 4. *Reliability of the System on the Blade Hub Ratio and Other Parameters*

Item	Cronbach's Alpha	CA if Item Deleted
P(W)	0.631	0.628
N_A (rpm)		0.475
N (Rpm)		0.406
% loss		0.658
N_T(rpm)		0.638
BHR		0.657

Table 5. *Reliability of the System on the Blade Twist Angle (BTA) and Other Parameters*

Item	Cronbach's Alpha	CA if Item Deleted
P (W)	0.530	0.666
N_A (rpm)		0.384
N (Rpm)		0.299
% loss		0.548
N_T (rpm)		0.530
BTA		0.552

Discussion

Figure 6 to 8 confirm the general expectation that the alternator shaft speed (N_A) improves with increasing flow rate, a function of flow area, which favors the development of higher torques (Edeoja et al. 2016a, Derakhshan and Kasaiean 2012, Park et al. 2012, von Flotow 2012, Smith and Bush 2010). Also, it has been shown for this system that N_A increases with the number of blades (*NOB*) before deteriorating after about 10 to 12 blades (Edeoja et al. 2016c). Figure 6 shows that N_A steadily increased with NOB for the range of penstock outlet diameter (*POD*) of 20 mm ≤ *POD* ≤ 25 mm as against a decrease after *NOB* = 9 for *POD* ≤ 17.5 mm. The value for *POD* = 20 mm were generally the highest including the ones within the 20 mm ≤ *POD* ≤ 25 mm range. This confirms the tendency of flow acceleration increasing with area reduction until a turning point is attained depending on the initial area. The values for *POD* = 22.5 and 25 mm generally agree with the fact that larger diameters support higher flow rates resulting in large values of N_A (Tamrakar et al. 2015, Al Amin and Talukder 2014, At-Tasneem 2014, Martins and Sharma 2014, Sangal et al. 2013, Yassi and Hasemloo 2010). Hence, the combination of an optimum *POD* = 20 mm and increasing *NOB* favors the production of good torque and as a result improved N_A.

Figure 7 shows that the pattern of variation of N_A for the respective *PODs* was not well defined below blade twist angle (*BTA*) of 60°. Apart from some likely errors of alignment, this could largely be attributed to insufficient blade surface area of blade available for the water jet to strike. For *BTA* ≥ 60° however, for all the values of *POD*, N_A increased steadily with *BTA*, peaking around 75° before deteriorating. However, for *POD* = 15 mm, N_A did not deteriorate because the reduced flow area was compensated for by the greater blade surface area available for interaction with the water jet. On the whole, *BTA* varied with N_A in the range 20 mm ≤ *POD* ≤ 25 mm in a similar fashion as the case with *NOB* vis a vis being highest for *POD* = 20 mm followed by 22.5 mm and the 25 mm. Hence, *BTA* ≥ 75° and *POD* = 20 mm will favour larger values of N_A.

Figure 8 shows the variation of hub to blade ratio (*HBR*) with N_A. It also generally indicated that N_A was higher for the range 20 mm ≤ *POD* ≤ 25 mm, with the values for *POD* = 20 mm being also highest followed by the others as before. Also, the general tendency was for N_A to peak at *HBR* = 0.55 which agrees with the range of values reported by several researchers (Pacayra et al. 2016, Williamson et al. 2011, Simpson and Williams 2011, Sopian and Ab Razak 2009). This was not however significant for *POD* = 25 mm probably because the increased flow rate for the larger diameter outlet compensated for all the other values of *HBR*. Hence, *POD* ≥ 20 mm and *HBR* = 0.55 favor the development of higher values of N_A.

Figures 9 to 11 display the variation of N_A with *POD* for the other three parameters. They generally agree with the foregoing discussions. They respectively show that 12 blades, *BTA* ≥ 75° and *HBR* = 0.55 along with *POD* = 20 mm favour a good performance in terms of the N_A attained. On a general note, high values of N_A lead to larger power outputs. Hence, the combination of these parameters yielding high N_A should potentially produce large power output.

Figures 12 to 14 show the relationship between the system's computed power with *NOB*, *BTA* and *HBR* for the various *POD*s. The figures bear some resemblance to Figures 6 to 8 expectedly because the power generated in a conventional hydropower system depends more or less directly on N_A (Alnakhlani et al. 2015, Ridzuan et al. 2015, Chukwuneke et al. 2014, Yadav and Chauhan, 2014, Katre and Bapat 2014, Ho-yan 2012, Ho-yan 2011, Pengchang et al. 2006). In Figure 14, however, the variation of the computed power with *BTA* for *POD* = 20 mm did not resemble the pattern shown in Figure 8. This probably could have been as a result of some alignment and measurement errors. It was nonetheless above the trends for *POD* ≤ 17.5 mm, thereby affirming that the range 20 mm ≤ *POD* ≤ 25 mm favors good system performance. Along with this range of *POD*, Figure 13 shows that *NOB* = 12 yielded the highest computed power of > 5000 W. Also, *BTA* ≈ 75° gave the highest computed power for the same range as shown in Figure 14. Figure 15 also indicated slightly that *HBR* = 0.55 produced the highest power output though for all values of HBR, the computed power for the range 20 mm ≤ *POD* ≤ 22.5 mm were all > 5000 W.

Figures 15 to 17 show the relationship between the computed power and the PODs for the various NOB, BTA and HBR. They further strengthen the findings reflected in Figures 12 to 14. Hence, for the system, the condition that 20 mm ≤ *POD* ≤ 22.5 mm, *NOB* = 12, *BTA* ≥ 75° and *HBR* = 0.55, favor large power generation. For the ongoing development of a clean, decentralized and highly simplified energy system, these findings represent very good indications for the actual implementation for end user applications.

Tables 1 and 2 indicate that *BHR*, *BTA*, *NOB* and % loss have no statistically significant relationship with (or effect on) the power of the system with $p > 0.05$. However, *POD* has a highly significant effect on the power with $p < 0.05$. Furthermore, each of *POD* and *BTA* individually has a highly significant relationship with each of N_T, N_A and N with $p > 0.05$ for each case which in turn individually has a highly significant relationship with power ($p < 0.05$). It is noteworthy that the relationship of *BTA* with the N-parameters is negative such that as one increases the other is expected to decrease. On the other hand, each of *BHR* and *NOB* individually has no statistically significant effect on the N-parameters and % loss ($p > 0.05$) and hence, on the power of the system. % loss has no significant relationship with any of the parameters except N_A. Meanwhile, the relationship is negative such that the lower the former the higher the latter.

Hence, N_A is the most critical of all N-parameters, agreeing with what has been established earlier on in the discussion. High N_A is desired for high power and low % loss. In order of preference, high *POD* is desired for increasing both N_A and power followed by lowering *BTA* for increasing N_A. *BHR* and *NOB* have no statistically significant consequences at this level.

Cronbach's alpha (*CA*) is used to test the extent of reliability of the performance of the system on the parameters. When *CA* > 0.05, it means that a statistically highly significant reliability level exists. The value of *CA* when a parameter is removed from the system is also given as shown in Tables 3 to 5. From the tables, the performance of the system has a highly significant reliability on the *NOB*, *BHR* and *BTA* combined with other identical parameters because of their high *CA* values of 0.692, 0.631 and 0.530 respectively. This is indicated from the respective values of turbine and hence alternator shaft speeds. Low values of these parameter result in reduction in *CA* values. This means that the system performance most highly relies on the value of these parameters. Also, *CA* would be highly improved when % loss is reduced in the system. Hence, the performance least significantly relies on % losses and so, all effort must be made to remove % losses. However, since the *CA* value when each of *NOB*, *BHR* and *BTA* are respectively removed from the system is only higher for *BTA* than when % loss is removed in Table 5, it implies that the system performance relies more on *BTA* than % loss with the reverse is applicable for *BHR* and *NOB*. Hence, N_A and N are very critical to the performance of the system. They must not be removed. % loss must be removed from the system to improve the performance. Also, the performance of the system significantly relies on *NOB*, *BHR* and *BTA*. However, the reliability of the systems improves when either is removed from the system. On the whole, a perfect match exists between the conclusions drawn from the two tests.

Conclusions

Based on the results obtained from the study, the following conclusions can be drawn for further development of the system with a view of improving performance and achieving end user status for small scale power generation:

1. For the v-blades configuration this particular Pico-hydro system, a 20 mm penstock outlet diameter with a 12 blade runner is appropriate for use.

2. The combination of flat blade twist angles in the range $75° \leq \theta < 90°$ with penstock outlet diameters in the range > 20 mm have very good potential for use on the Pico hydropower system with possibility for scaling to suit specific requirements for system performance.

3. In addition to the issues raised, the study also confirms that the hub to blade ratio of 0.55 is appropriate for this system.

The findings strengthens the resolve to keep striving in order to actualize the target of adding this system as an end user energy solution which is clean, environmentally benign and less vulnerable to sabotage into the energy mix in Nigeria. The following recommendations/suggestions are made for further improvement of the performance of the simplified Pico hydro system:

1. Turbine casings used should have adequate provision for the runner not to run through the water so that drag forces on it can be minimized.
2. The effects of water jet misalignments will be further reduced by incorporating provision(s) for such in further designs.
3. Larger diameter pipes should be used in transferring water to the overhead tank to sustain the flow circle at the expense of justifiable higher cost.
4. Larger and/or multiple reservoirs will also be explored to enhance the robustness of the system.
5. Lighter metals such as aluminum should be used in fabricating the runners and blades as heavier metals like mild steel add to the inertia and thus decrease turbine performance.
6. The option of hybridization with solar energy is very viable in the location of the work and will be explored with better access to funding.

Most importantly, a general awareness and technical understanding of successful Pico-hydro technology needs to be developed and fostered at the local and regional levels so that rural electrification projects can be boosted.

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