

## **Electrical Engineering Centrifugal Pumps Vibration**

Quantitative Research Proposal Centrifugal Pumps Vibration – Causes and Solutions

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### **Abstract**

This quantitative research proposal is based on the causes of vibration in centrifugal pumps and the ways to reduce it. It is highly necessary to be concerned about the vibration which outcomes from the centrifugal pump as it mainly affects the performance output of the pump. It is better if the vibration is monitored on the first time so that it can be eliminated suitable damping techniques or tightening the loosened fasteners. Some of the components which are seriously affected by vibrations are

- Shaft: Improper shaft movement affects the life of the mechanical seal. Vibration in the shaft movement may cause chipping of the carbon face and may open the seal face.
- Packing: The radial movement of the shaft is directly related to the packing and the packing is extremely sensitive. The vibration not only causes excessive leakage but also causes wear in sleeve and shaft. The vibration gives high friction leading to excessive heat dissipation. So additional flushing will be needed to control the heat dissipated in the pump.
- Bearings: The load from axial and radial movement are handled by bearings. The bearings are not designed for vibration and it cannot withstand abnormal vibrations. So the vibration causes dent on races of the bearing which may lead to severe damage of the bearings.
- Rings and impeller: Critical dimensions and tolerances will be provided during designing of pumps. So the vibration affects the wear ring clearance and impeller setting.
- Seals: They are very sensitive to the radial movement of the shaft. Due to vibration caused in the pump, the seals will get damaged prematurely which increases shaft damage. Another seal called labyrinth seal, which operates in a very close tolerance. If the vibration is excessive those tolerances will be damaged very easily.

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**Subject Code:** \_\_\_\_\_ Subject Name: Introduction to Behavioral Science, Section 01

**Course Number:** 00100-BE 0001-Beginning Progress 0001

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## QUANTITATIVE RESEARCH PROPOSAL

### CENTRIFUGAL PUMPS VIBRATION – CAUSES AND SOLUTIONS

#### 1. THE PROBLEM AND ITS SETTING

Centrifugal pumps belong to the subclass of dynamic axisymmetric fluid absorbing turbo machinery which transports fluid by converting the rotational kinetic energy to the hydrodynamic fluid flow. The rotational motion can be achieved either by a motor or an internal combustion engine. Centrifugal pumps are commonly used in water, petroleum, sewage and petrochemical pumping. Such a useful machine has a common problem called vibration which leads to a major maintenance costs. The causes of the vibration occurring in this pump can be generally classified into mechanical causes, system causes, hydraulic causes, operational causes and other causes. These causes of vibrations to major losses and reduced life of the pump. Engineers who came to know about the issue finally found the solutions of each and every cause of vibration which reduced the maintenance costs but did not stop the vibration. More explanation about the causes and solutions are discussed in detail in the upcoming chapters.

**Keywords:** dynamic<sup>1</sup>, axisymmetric<sup>2</sup>, turbo<sup>3</sup>, kinetic energy<sup>4</sup>, hydrodynamic<sup>5</sup>, internal combustion engine<sup>6</sup>, hydraulic<sup>7</sup>.

**Commented [A1]:** Appropriately put in words

<sup>1</sup> Characterized by action or forcefulness or force of personality

<sup>2</sup> An object having cylindrical symmetry

<sup>3</sup> A mechanism that converts fluidic energy into rotational energy

<sup>4</sup> The mechanical energy that a body has by virtue of its motion

<sup>5</sup> study of liquids in motion

<sup>6</sup> A heat engine in which combustion occurs inside the engine rather than in a separate furnace

<sup>7</sup> Moved or operated or effected by liquid

## 2. THE ASSUMPTIONS

Let us consider two identical centrifugal pumps A and B. Pump A is not optimized for vibration and pump B is optimized to reduce vibrations. It is assumed that, after 100 hours of running, the pump A will get affected in various parts like shafts, bearings, rings and impeller, seals and fasteners. But the pump B which is damped by all aspects in vibration, will not get affected as the vibration is considered from each and every part which it originates and it is perfectly damped. The efficiency of the pump A is very less than pump B because due to vibration, the pump A cannot work in a definite manner thereby producing less output.

## 3. THE DELIMITATIONS

In today's mechanics, and considering the centrifugal pumps, the common issue which is occurring in that pump is vibration. There are several other problems which are common are corrosion, priming, etcetera. But those problems can be easily avoided by changing the material of the parts or treating it with non-corrosive substance. But the vibration occurs in almost all working parts in the centrifugal pump. Also, there is no possibility of eliminating the vibration totally. But it can be damped which reduces the vibration and not eliminating it.

## 4. THE STATEMENT OF THE PROBLEM AND SUB PROBLEMS

This quantitative research proposal is based on the causes of vibration in centrifugal pumps and the ways to reduce it. It is highly necessary to be concerned about the vibration which outcomes from the centrifugal pump as it mainly affects the performance output of the pump. It is better if the vibration is monitored on the first time so that it can be eliminated suitable

damping techniques or tightening the loosened fasteners. Some of the components which are seriously affected by vibrations are

- **Shaft:** Improper shaft movement affects the life of the mechanical seal. Vibration in the shaft movement may cause chipping of the carbon face and may open the seal face.
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- **Rings and impeller:** Critical dimensions and tolerances will be provided during designing of pumps. So the vibration affects the wear ring clearance and impeller setting.
- **Seals:** They are very sensitive to the radial movement of the shaft. Due to vibration caused in the pump, the seals will get damaged prematurely which increases shaft damage. Another seal called labyrinth seal, which operates in a very close tolerance. If the vibration is excessive those tolerances will be damaged very easily.
- **Bolts:** The vibration can also cause the bolts and other fasteners to get loosened which leads to multiple vibration and noise. (Nally, n.d.)

**Commented [A2]:** The section has been very elaborately dealt with.

## 5. THE REVIEW OF THE RELATED LITERATURE

H.F.Black who analyzed the effects of hydraulic forces in annular pressure seals on the vibrations of centrifugal pump rotors. He said that in centrifugal pumps, the leakage path is covered with annular clearance spaces which is otherwise called as impeller seals and balance piston seals. This acts as a powerful hydrostatic bearings during turbulent flows. The author analyzed the dynamic forces acting on the rotor due to the bearings in this discussion which includes the squeeze action<sup>8</sup>. Using a single mass motor which includes the estimation of amplitudes and critical speeds, the author analyzed the synchronous forces. Marcinkowskij and Karincev made a qualitative agreement found in large damping forces which was happening due to the squeeze action. The author did a simplified treatment for the fluid rotation effects which was included in the analysis of the rotor vibrations. (Black, 1969)

Rodriguez.C.G, Egusuiza.E, and Santos.F did a research on measuring the frequencies in the vibration induced by the rotor stator interaction in a centrifugal pump turbine. They said that most of the higher level vibrations in large pump turbines are generally originated from the RSI<sup>9</sup>. There are some specific characteristics of vibration which can be clearly observed from the frequency domain such as, a particular relationship between their amplitudes and harmonics of a moving blade which passes frequencies. An appropriate tool which is used to determine the force and its characteristics is the CFD model<sup>10</sup>. The vibration which is induced by the RSI is predicted by considering the sequence of the interaction and also different amplitudes in the interaction between same moving blades and different stationary blades. This gives a different and original interpretation about the source of the vibration

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<sup>8</sup> the velocities of separation effects or the approach of bearing and journal surfaces

<sup>9</sup> Rotor Stator Interaction

<sup>10</sup> Computational Fluid Dynamics model

characteristics. This action proposed was successful as a consequence of this new interpretation. (Rodriguez, et al., 2007)

## 6. DATA AND THE TREATMENT OF DATA

### A. Data needed and the means for obtaining data

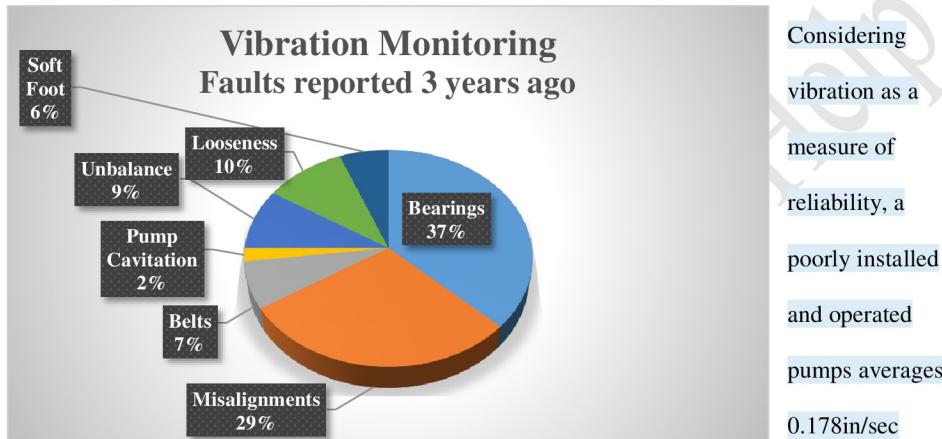
The data required will be recorded like the vibration monitoring. The vibration can be measured by using several instruments which can measure the amount of vibration causing in the centrifugal pump. The vibration can be measured in terms of frequencies and also in hertz.

### B. The research methodology

The main research method is to use a real time motor and a centrifugal pump and to test the vibration which is occurring in the various parts in the pump. The problems are noted down and various ways are figured out to dampen the vibrations. If all the vibration here are damped, we can assume that the pump can run with less vibration which will not much affect the performance and the parts of the pump.

## 7. THE IMPORTANCE OF THE STUDY

The vibration is the fact that causes the drop in performance of centrifugal pumps. A survey was taken from the service department of centrifugal pumps who explained that, the faults are mainly on the bearings of the pump which gets easily affected due to vibration.



Considering vibration as a measure of reliability, a poorly installed and operated pumps averages 0.178in/sec

overall vibration and will have 6 months of life. But a properly installed pumps averages 0.071in/sec overall vibration and will have 60 months of life. The below pie chart explains about the faults which were reported on failure of centrifugal pumps 3 years ago.

The causes of these vibrations shall be generally classified in to three types

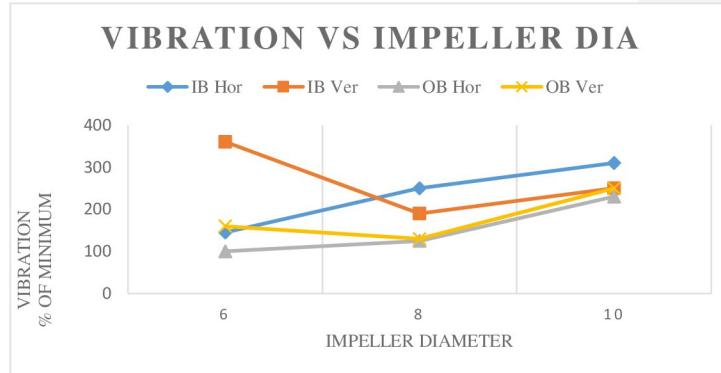
- Mechanical causes
- Hydraulic causes
- System induced
- Operationally induced
- Other causes

#### 4.1. Mechanical causes

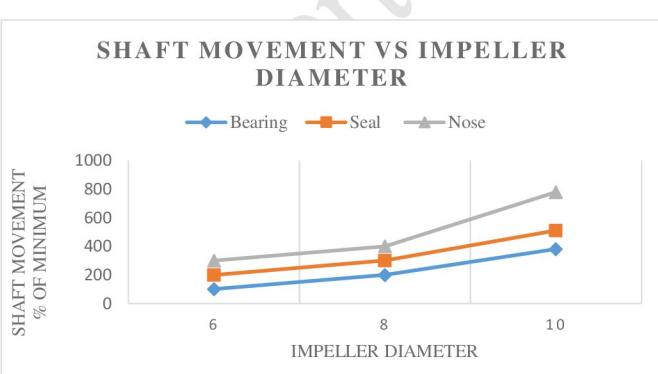
When a pump fails due to the vibration induced by mechanical parts, then it is considered as

mechanically induced. Some of mechanically induced causes are explained below.

- Bad bearings
- Bent shaft
- Unbalanced rotor
- Check valve installed backwards
- Misalignment
- Looseness
- Soft foot
- Maximum size impeller
- Pipe strain
- Rubbing parts (Anon., 2013)
- Thermal growth (Kutin, 2009)



**Commented [A3]:** Explanations with depicted graphical representations helps enhance quality of work.



#### 4.2. Hydraulic causes

There are some hydraulic properties which causes vibration in centrifugal pumps. Some of them are listed below.

- Operating after the pump's BEP<sup>11</sup>
- Product vaporization
- Vane of the impeller running very close to the pump's cut water
- Internal recirculation
- Air entering into the system through vortexing (Qualtex, n.d.)
- Turbulent flow into the system
- Water hammer (Taneja, 2013)

#### 4.3. System induced

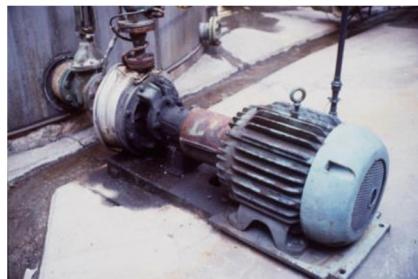
Some of the vibrations which is induced by the system. They might happen due to a mistake during the installation or some faults by the manufacturer or mistakes made by the user.

- Partially/Plugged strainer
- Clogged impeller or suction line
- Installation
- Foundation and base plates

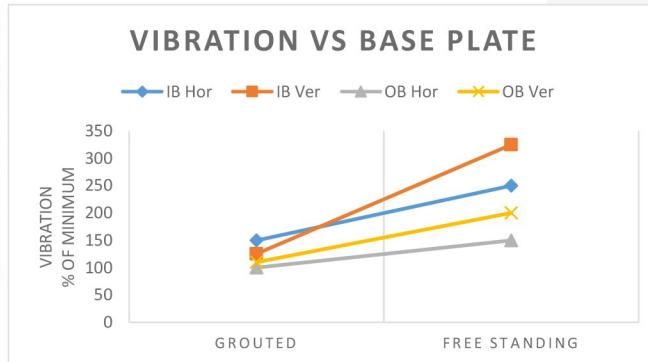
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<sup>11</sup> Best Efficiency Point

The foundation and base plates are the important part to dampen the regular vibration which occurs during regular working of the centrifugal pump. The mass ratio of the foundation



or base plate should be in the ratio of 3:1 to minimize vibration. (Weinman, n.d.)



The vibration caused during the operation of the centrifugal pump is called operationally induced. The four main causes of the operationally induced vibration are

- Cavitation
- Flow
- Speed
- Insufficient immersion of suction pipe or bell

#### 4.4. Other causes

- Harmonic vibration coming from nearby equipment
- Handling the pump at critical speeds. This problem is common in variable speed and pulley driven pumps
- Slip stick must be sealed at the seal faces. This may occur when a non-lubricating fluid or gas or dry solid is pumped.

- When a pump discharge recirculation line is aimed at the seal faces, it causes severe vibration.

## 8. THE HYPOTHESES

An obvious solution to the problems mentioned above is to adopt good maintenance that will eliminate almost all the vibration. Also a hardware must be installed, which can live with the vibration. Recording the vibration range regularly will support good maintenance. The solutions for the mechanical, hydraulic and other problems were determined by engineers after some research.

### 5.1. Mechanical problem solutions

- Balancing every rotating equipment shall reduce the vibrations. If a plant does not have any dynamic balancing equipment, there are many available contractors and vendors who are ready to balance these equipment. If the pump is working by pumping abrasives or slurries, it is better to have a dynamic balancing equipment as the pump imbalances while pumping solid components.
- If bent shafts creates problem during running, it can be straightened. But it will not be successful on all times. In such a situation, it is better to replace the shaft rather than wasting time in straightening it.
- The pump foundation is advised to construct using concrete. The mass of the foundation must be five times larger than the mass of the centrifugal pump, base plates and the other equipment which is supported to it.

- The foundation must be 3 inches wider than the base plate for the power of the pump up to 500HP. For the pumps higher

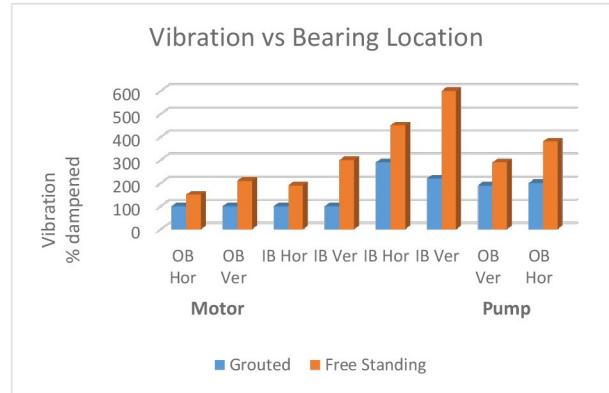
than 500HP should have the foundation width of 6 inches.

- Every single inch of stainless steel grows about 0.001 inch for every 100°F rise in temperature. This thermal growth will cause the impeller to touch the pump casing which may cause vibration. It is better to use carbon steel as it grows 30% lesser than stainless steel.

## 5.2.

### Hydraulic problem solutions

- User must ensure if there is enough NPSH for their application. If NPSH<sup>12</sup> is not sufficient, an inducer or a booster pump can solve this problem.
- A simplest solution to avoid air entering into the system is to replace the pump packing with a balanced o-ring seal. If there is a problem with vortexing, the user is advised to consult the Hydraulic Institute Manual to obtain information on vortex breakers and proper piping layouts to prevent turbulence in the lines and also in the pump section.



<sup>12</sup> Net Positive Suction Head

- It is good to use the suction pipe of a larger diameter than in the pump. Then a reducer can be used to connect the pipe with the pump. It is recommended not to use concentric reducers.

### 5.3. Solutions to other type of vibration

- Problems regarding critical speeds are not common unless the pump is a variable speed type. In such case changing the speed will solve the problem. Or else changing the impeller diameter will solve this issue.
- Sealing the slip stick is a problem with non-lubricants like hot water or other solvents. If o-ring seals are used, it acts as a vibration damper. Metal bellow seals require vibration damper to be installed separately.
- Whenever the impeller passes the recirculation line, the pump discharge recirculation lines vibrates. This type of vibration will affect the mechanical seal. This can be solved by chipping on the outer diameter of carbon face and worn drive lugs.

## 9. AN OUTLINE OF THE PROPOSED STUDY

The steps are required as follows

- Couple the motor with the centrifugal pump ensure the fasteners are perfectly tightened
- Connect the vibration measuring device in the places were the pump is assumed to exert vibrations
- Switch on the pump and let the pump to run for sometime

- Observe the vibration causing places and measure the efficiency of the pump at regular times
- At each and every vibration places, dampen the vibration which is currently causing and make a note of the pump's efficiency
- Once the current vibration is damped, make a note of the amount of vibration damped and the amount of vibration remaining

**Commented [A4]:** All sections are very well covered and main points clearly stated to support research.

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<b>Criterion</b>	<b>Levels of achievement</b>		
	<b>Exemplary</b>	<b>Good</b>	<b>Poor</b>
<b>Writing style and presentation are clear</b>			
• Title	<p>Title is concise and informative so readers can anticipate the contents of the contribution and interested people look forward to reading it.</p>	<p>The title gives a general indication of the material covered in the contribution, but have to read the document to fully appreciate what is covered. Some potential readers may be lost because they can't clearly anticipate the material covered by reading the title.</p>	<p>The linkage between the title and the text is not clear. Reader may skip the contribution because they don't appreciate its relevance.</p>
• Introduction	<p>Introductory statement clearly indicates the main purpose of the contribution and suggests the plan of organization, so the reader can anticipate the text that will follow.</p>	<p>Introductory statement indicates the main purpose of the contribution in general terms, so the reader has some idea of what will follow.</p>	<p>The introduction does not give an overview of the contribution so the readers are not sure what to expect as they read the text.</p>

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• Written expression	Sentences and paragraphs are well structured and clear so the reader can focus on	Minor lapses in sentence structure, such as run-on sentences and unnecessarily complex sentence structures,	Many sentences are poorly structured so the reader must stop often to reflect on

	what is written. Each paragraph has a topic sentence that indicates the subject matter.	force the reader to pause and reflect on the meaning of the text. Paragraphs present a complete argument, but may not flow so well.	the meaning of the text. Many paragraphs lack topic sentences or have poor flow so the main points and linkages among explanatory text are not clear.
• Grammar, punctuation and spelling	Grammar, spelling and punctuation are flawless, which allows the reader to focus on the message.	Some minor errors in grammar, spelling and/or punctuation detract from the quality of the text, but do not impair the communication.	Many errors in grammar, spelling and/or punctuation make reading the text difficult and communication is impaired.
<b>Concepts and arguments are well developed</b>			
• Accuracy	All information is accurately reported using appropriate terminology	The information is largely accurate but imprecise language could lead a reader to misinterpret aspects of the text.	Although the gist of the information is correct, there are problems with the interpretation of it.

	so the information is reliable.		A reader can be misled by the text.
• Relevance	Connections between the contribution and the main topic of the discussion are clearly indicated.	Connections between the contribution and the main topic of the discussion are indicated or implied, but the reader needs to pause to clarify those connections.	Although the text is relevant, this is not clearly indicated, so the reader must guess how the text relates to the main topic.
• Significance	The reason why the contribution is important to the overall discussion is clearly described and discussed so the reader takes the contribution seriously.	The reason why the contribution is important is touched on but not elucidated, so the reader must make some interpretations about the author's view of the contribution's significance.	The contribution may include significant material but this is not indicated, so the reader must guess it.
• Clarity	The main points and new technical terms are clearly described and/or explained so the reader is	Although the text is clear to informed audiences, unexplained points may leave room for alternative interpretations of the text.	Key points and new technical terms are not explained so the reader is confused.

	left with no ambiguity about what was written.		
• Independence	The contribution is completely self-contained so the reader does not have to read other contributions or published materials to understand what was written about.	The text is sufficiently clear that the reader can understand the main point without further reading, but some parts of the text are not clear without consulting earlier contributions or other sources of information.	The text is written in a manner that presumes considerable prior knowledge, so the reader must have a thorough knowledge of what has been written about the subject in order to understand the main point of the contribution.
<b>Contribution is responsive to another contribution</b>	The writer links ideas submitted by others to their own contribution in a manner that substantially strengthens the group's efforts to resolve the main	The writer makes references to earlier works that are a starting point for new ideas but, apart from the reference to the earlier work, not much information is incorporated	The text mentions other contributions but neither explains the reference nor substantially adds to it, so there is no clear benefit to the

	<p>problem. This linkage can include elaboration of what was previously written, a critique or questioning of it, demonstration of linkages among two or more earlier contributions, and/or utilization of an earlier contribution as a foundation to build your own.</p>		<p>resolution of the main problem from citing the earlier contribution.</p>
<b>Text is supported by references</b>			
• Sources indicated	<p>All information and ideas that are not commonly known are supported with references to sources, so the reader has confidence that the information is not based on hearsay or</p>	<p>Most sources are indicated, but in only a few cases the sources are not given or are ambiguous, so the reader has to check some of the sources.</p>	<p>Sources are cited for some specific parts of the contribution, but no references are supplied for information and ideas that are</p>

	<p>the writer's opinion or assumptions alone.</p>		<p>clearly not the author's, so the reader has no idea of the validity and authority of the information.</p>
• Relevant references	<p>Information, concepts and opinions are supported with references to published literature, especially primary (original) sources of information, rather than review articles or textbooks. This allows the reader to independently review the cited sources. More than one reference is cited to support key points, which adds</p>	<p>One or a few references are used to support the text. Thus the contribution is supported but this may be an idiosyncratic source. Some general references to textbooks are made that could have been replaced by primary references which are more thorough and authoritative.</p>	<p>Information comes from Web sites or other sources that have no recognized authority, so the validity or strength of the source is unknown.</p>

	strength and authority to the argument.		
• Citation style	References cited appropriately in the text, and the correct format is used in the text when citing information, so the reader clearly knows which information is attributable to which source.	Minor lapses in citation format do not prevent the reader from finding the sources in the reference list at the end of the contribution.	Citation format incorrect or poorly placed in the text, so citations distract from reading.
• Bibliographic information	The reference list contains complete bibliographic information (author's name(s), publication date, title, source, date web page accessed), so a reader can easily find the references for their own research. The authority of sources can be	Bibliographic information largely complete, but some information missing so the reader may have difficulty finding some references. Most sources can still be easily checked.	Not all references are listed, information in the reference list is incorrect, or important information is missing from the reference list, so the reader is unable to find the same

	evaluated by checking them.		sources of information and the authority of sources is almost entirely unknown.
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**Faculty Comments:**

The research proposal is very well constructed and all important guidelines for research is embedded in the work. Also the sectional divisions have been justified with appropriate pictorial representations bringing out clarity.