

Design and Fabrication of a Gear Box Motor Current Analysis System

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Mechanical Engineering
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2010.



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CERTIFICATE

This is to certify that the project entitled “Design and Fabrication of a Gear Box Motor Current Analysis System” submitted by Madhurya Baruah and H A Rakshin in partial fulfillment of the requirements for the awards of Bachelor of Technology, NIT Rourkela (Deemed university) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge the matter embodied in the project has not been submitted to any Institute/University for the award of any degree or diploma.

Date: 12.05.2010.

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ACKNOWLEDGEMENT

It is a great privilege for us to express our deep sense of gratitude to our Guide Professor S C Mohanty, Department of Mechanical Engineering, NIT Rourkela for introducing the present topic and to provide us stimulating guidance, constructive criticism and valuable suggestion throughout this project. I shall always cherish my association with him for his constant encouragement and freedom to thought and actions that he rendered to me throughout this project.

Finally, we deem it a great pleasure to thank one and all those who helped us carry out this project.

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1.**ABSTRACT**

To achieve reliable and cost effective diagnosis, Motor current signature analysis is used to investigate the use of an induction motor as a transducer to indicate the faults in multistage gearbox via analyzing supply parameters such as phase current and instantaneous power.

In gearboxes, load fluctuations on the gearbox and gear defects are two major sources of vibration. Further at times, measurement of vibration in the gearbox is not easy because of the inaccessibility in mounting the vibration transducers. This analysis system can be used for measuring the characteristics for a perfectly working gearbox and use the data as a standard for measuring faults and defects in other gearboxes. The objective of this paper is to design and fabricate a gearbox motor current analysis system at different gear operations for a constant load. Steady load conditions on the gearbox are tested for current signatures during different gear operations.

The motor current analysis system can be used further to specify mainly faults in the gear, misalignment of meshed gears, and loss of contact of the gears.

2.

INTRODUCTION

The monitoring of a gearbox condition is a vital activity because of its importance in power transmission in any industry. Therefore, to improve upon the monitoring techniques and analysis tools for finding the gear ratios in the gearbox and the current passing through the motor running the gearbox, there has been a constant endeavor for improvement in these monitoring techniques. Techniques such as wear and debris analysis, vibration monitoring and acoustic emissions require accessibility to the gearbox either to collect samples or to mount the transducers on or near the gearbox. But dusty environment, background noise, structural vibration etc. may hamper the quality and efficiency of these techniques. Hence, there is a need to monitor the gearbox away from its actual location, which can be achieved through Motor current signature analysis (MCSA) which has already been successfully applied to condition monitoring of induction motor and in bearings. [2]

Motor current signature analysis has been used for several years as a diagnostic tool for electrical problems in ac induction motors. Personnel at Oak Ridge National Laboratory have found that MCSA can also provide information about system vibrations and imbalances similar to the information provided by an accelerometer. As a result, MCSA techniques for monitoring the status of the equipment, such as pumps, compressors and gear drives driven by induction motors have been developed and used in dedicated monitoring systems. In this work, researchers have found that MCSA responds proportionately to imbalances in rotating equipment and can be used to detect the high-vibration conditions that can result. Extensive test data support that MCSA has a number of inherent strengths, the most notable being that it: [11]

- Provides nonintrusive monitoring capability at a location remote from the equipment.

- Provides degradation and diagnostic information comparable to conventional instrumentation.
- Offers high sensitivity to a variety of mechanical disorders affecting operational readiness.
- Offers means for separating one form of disorder from another.
- Can be performed rapidly and as frequently as desired by relatively unskilled personnel using portable, inexpensive equipment.
- Is equally applicable to high-powered and fractional horsepower machines, ac and dc motors.[10]

MCSA is based on the recognition that a conventional electric motor powering a machine also acts as an efficient and permanently connected transducer, detecting small time dependent motor load variations generated within the mechanical system and converting them into electric current signals that flow along the cable supplying power to the motor. Also we can find in particular, if there are some faults in a gear box drive, the main current signal will be modulated by additional waveforms induced by fault components as shown in figure. [11]

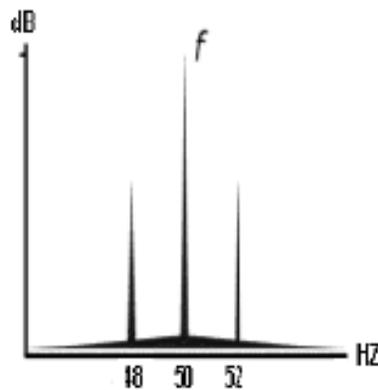


Fig 1: Sidebands of current signal

Reference: Gear box fault detection using motor current signature analysis, Mansaf R. Haram

3.

LITERATURE REVIEW

This chapter outlines some of the recent reports published in literature on different methods of fault analysis of a faulty gearbox. Gear box fault detection can mainly be done through vibration and motor current analysis. The former method uses the fact that Vibration Faults, when they begin to occur, alter the frequency spectrum of the gear vibration. Particular faults are identified by recognizing the growth of distinctive sideband patterns in the spectrum. [1] The spectrum is recorded with the help of oscilloscope when the accelerometer is placed on the gearbox to be tested.

The test department at RABA factory in Győr, Hungary has been involved in vibration testing of truck rear-axle-units. The testing consists of running the units to breakdown, on a specially constructed test bed. The gear vibration is monitored during the tests, to identify failure occurring. a special test stand is to drive the gears at constant speed and high load. on the test stand the output shafts are braked with eddy-current brakes, and the torque is controlled to maintain equal load and thus equal shaft speed on both output shafts, so the differential-compensating gears do not turn. It is the bevel-pinion gear and the crown-wheel gear that are the objects of the testing, and it is the vibration from these gears that is monitored.[1]

Fault diagnosis in a multistage gearbox under transient loads can also be performed using vibration analysis. An induction motor drives the multistage gearbox, which is connected to a DC generator for loading purpose. The signals studied are the vibration transients, recorded from an accelerometer fitted at the tail-end bearing of the gearbox; and the current transients drawn by

the induction motor. Three defective cases and three transient load conditions are investigated. Advanced signal processing techniques such as discrete wavelet transform (DWT) and a corrected multi-resolution Fourier transform (MFT) can be applied to investigate the vibration and current transients.[2]

Vibration monitoring is affected by the base excitation motion because of the presence of a number of machinery in the factory. Moreover, because of the intricate location of the machine, there may be a problem of mounting transducers on the gearbox at times. Similarly, the noise signature is affected by the background noise and the noise field. [5]

These limitations of prevalent techniques bolster the justification of using the motor current signature analysis (MCSA), which has already been used for condition monitoring of motor-operated valves of nuclear plants [3], [4], worm gears [5], induction motor and bearings [6]–[11], and multistage gearbox [12], [13].

MCSA is based on the recognition that a conventional electric motor powering a machine also acts as an efficient and permanently connected transducer, detecting small time dependent motor load variations generated within the mechanical system and converting them into electric current signals that flow along the cable supplying power to the motor. These signals, though small in relation to the average current drawn by the motor, can be extracted reliably and non intrusively and processed to provide indicators of the condition (signatures) of the motor. The trend of these signatures can be determined over time to give information concerning the motor and the load.

The basis of fault detection is the difference in normalized current RMS values of both healthy and faulty bearings. Broken rotor and eccentricity in the rotor and stator of an induction motor result in side bands of electric supply line frequency. Prior knowledge of spatial position of fault and the load torque with respect to the rotor is necessary as the effects of load torque and faulty conditions are difficult to separate.

Current signals can be analyzed in the time-domain or the frequency-domain. The former is also capable of analyzing systems during transients, such as during the initial or final operation of the system. MCSA requires amplitude information of the motor currents. The currents have imbedded information on the driven loads, with the information being available in the frequency domain or the time domain. To obtain rotor speed, frequency-domain analysis is chosen.

Motor current signals can be obtained from the outputs of current transducers which are placed non intrusively on one of the power leads. The resulting raw current signals are acquired by computers after they go through conditioning circuits and data interfaces.[14] These signals are then studied to determine faults occurring in gearbox.

Although numerous techniques are available of non intrusive type of testing for fault detection, they have their own limitations. The present work thus aims to develop and propose a method which is simpler and takes limitation of the present techniques into account.

Objectives of Research work

- To understand the limitation of these techniques in determining faults
- To propose a simpler technique of fault detection this takes care of these limitations into account.
- To conduct experiments based on these proposed technique

4**EXPERIMENTAL SETUP**

The experimental set up consists of a two-pole three-phase induction motor coupled to a 4-speed automotive gearbox. The output shaft of the gearbox is connected to magnetic brake which acts as a load. By varying the voltage with the help of a Variac the load on the gearbox could be changed when required. The input speed of the gearbox is the mechanical speed of the induction motor. In addition, the induction motor is also connected to variable frequency drive which controls the rotational speed of the motor by varying the input frequency which further controls the speed of the gearbox output shaft. Then there are current probes to measure the current response.

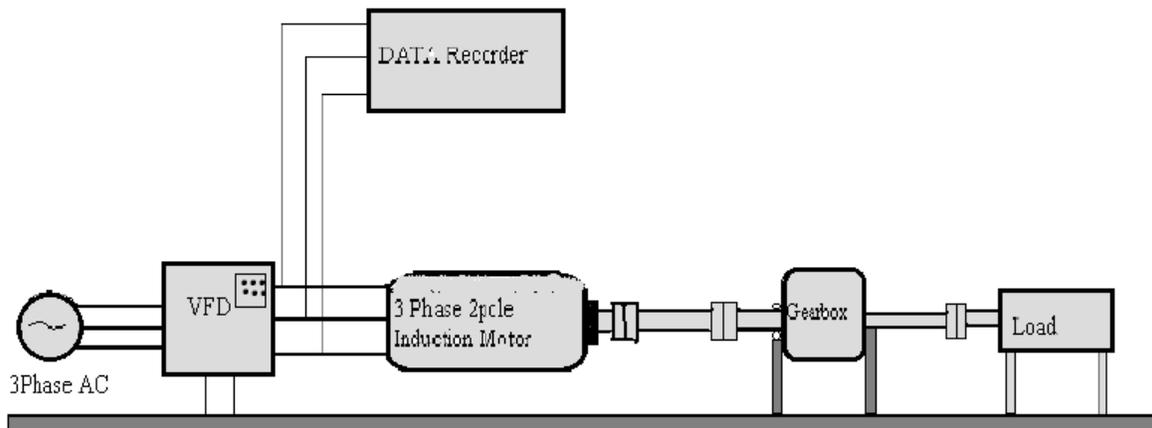


Fig 2: Schematic diagram of Experimental setup.

Description of various parts of the experimental setup is as follows:

4.1: 3 Phase Induction Motor

An electric motor converts electrical power to mechanical power in its rotor or rotating part. An induction motor is a type of alternating current motor where power is supplied to the rotor by means of electromagnetic induction. In an induction motor the power is induced in the rotating device unlike the DC motor where this power is supplied to the armature directly from a DC source. An induction motor is also called rotating transformer because the stator is essentially the primary side of the transformer and the rotor is the secondary side. The primary side's current creates an electromagnetic field which interacts with the secondary side's electromagnetic field to produce a resultant torque, thereby transforming the electrical energy into mechanical energy. Induction motors are widely used, especially poly-phase induction motors, which are frequently used in industrial drives. Induction motors are preferred over the DC motors due to their rugged construction, absence of brushes and the ability to control the speed of the motor.

There are three types of rotor

- Squirrel-cage rotor
- Slip ring rotor
- Solid core rotor



Fig 3: 3 phase Induction motor used in the experiment

The one used in the experiment is squirrel cage motor which has the following configuration

- Make: Siemens
- Rated Power: 2.2 kW.
- Rated Speed: 2850 rpm
- Frequency: 50 Hz.
- Voltage: 415 V.
- Current: 4.3 A.

4.2: Variable Frequency Drive

A variable-frequency drive is an electronic controller that adjusts the speed of an electric motor by modulating the power being delivered. It is a system for controlling the rotational speed of an alternating current electric motor by controlling the frequency of the electrical power supplied to the motor. Variable-frequency drives (VFD) can be of considerable use in starting as well as running motors. A VFD can easily start a motor at a lower frequency than the AC line, as well as a lower voltage, so that the motor starts with full rated torque and with no inrush of current.

When an induction motor is connected to a full voltage supply, it draws several times (up to about 6 times) its rated current. As the load accelerates, the available torque usually drops a little and then rises to a peak while the current remains very high until the motor approaches full speed. By contrast, when a VFD starts a motor, it initially applies a low frequency and voltage to the motor. The starting frequency is typically 2 Hz or less. Thus starting at such a low frequency avoids the high inrush current that occurs when a motor is started by simply applying the utility (mains) voltage by turning on a switch. After the start of the VFD, the applied frequency and voltage are increased at a controlled rate or ramped up to accelerate the load without drawing excessive current. This starting method typically allows a motor to develop 150% of its rated torque while the VFD is drawing less than 50% of its rated current from the mains in the low speed range.

Benefits:

Single-speed drives start motors abruptly, subjecting the motor to high torque and current surges up to 10 times the full-load current. In contrast, variable-frequency drives offer a "soft start" capability, gradually ramping up a motor to operating speed.



Fig 4: Variable Frequency Drive used in the experiment

The VFD used in the experiment has the following configuration

- Make: Prostar.
- Rated Power: 3.7 kW
- Voltage: 380 V
- Current: 5 A
- Frequency: Input: 50 Hz
 Output: 0-240 Hz
- Type: 3 phase
- Weight: 4.5 kg

4.3: Operational Process:

Operation process of setting frequency with keypad panel and starting in forward direction only[4]:

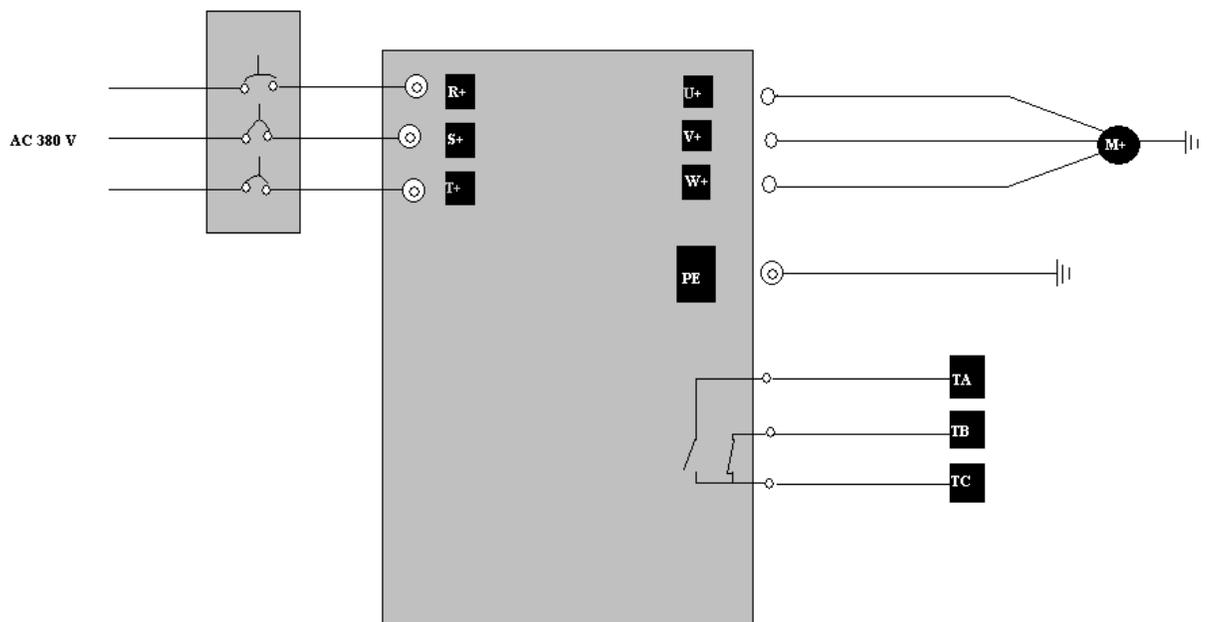


Fig 5: Wiring diagram: 1.

1. Connected the wires in accordance with the circuit diagram as above. After checking the wiring successfully VFD was powered on.
2. Entered the programming menu using “Mode” key.
3. Measured the functional parameters of the motor.
4. Entered F801 parameter and set the rated power of the motor to 2.2 kW.

5. Entered F802 parameter and set the rated voltage of the motor to 380 V.
6. Entered F803 parameter and set the rated current to the motor to 4.3 A.
7. Entered F804 parameter and set the number of poles of the motor to 2.
8. Entered F805 parameter and set rotary speed of the motor to 1440 rpm.
9. Entered F800 parameter and set it to 1 or 2 to allow measuring the parameter of the motor (1= running parameter mode, 2=static parameter mode. In the static parameter mode motor was supposed to be disconnected from load.).
10. Pressed “Run” key to measure the parameters of the motor. After completion of the measurement, the motor stopped running and relevant parameters were stored in F806-F809.
11. Set the functional parameters of VFD.
12. Entered F106 parameter and set it to 0; selected the control mode to sensor less vector control.
13. Entered F203 parameter and set it to 0.
14. Entered F111 parameter and set it to frequency 50.0 Hz.
15. Entered F200 parameter and set it to 0; selected the mode of start to keyboard control
16. Entered F201 parameter and set it to 0; selected the mode of stop to keyboard control.
17. Entered F202 parameter and set it to 0; selected corotation locking.

18. Pressed the run key to start the VFD.

19. During running, current frequency was changed by pressing or

20. Pressed the “Start/Stop” key once, the motor decelerated and it stopped running.

21. Switched off the air switch and de-energize the VFD.

Operation process of setting the frequency with keypad panel, and starting forward and reverse running, and stopping the VFD through control terminals [4] :

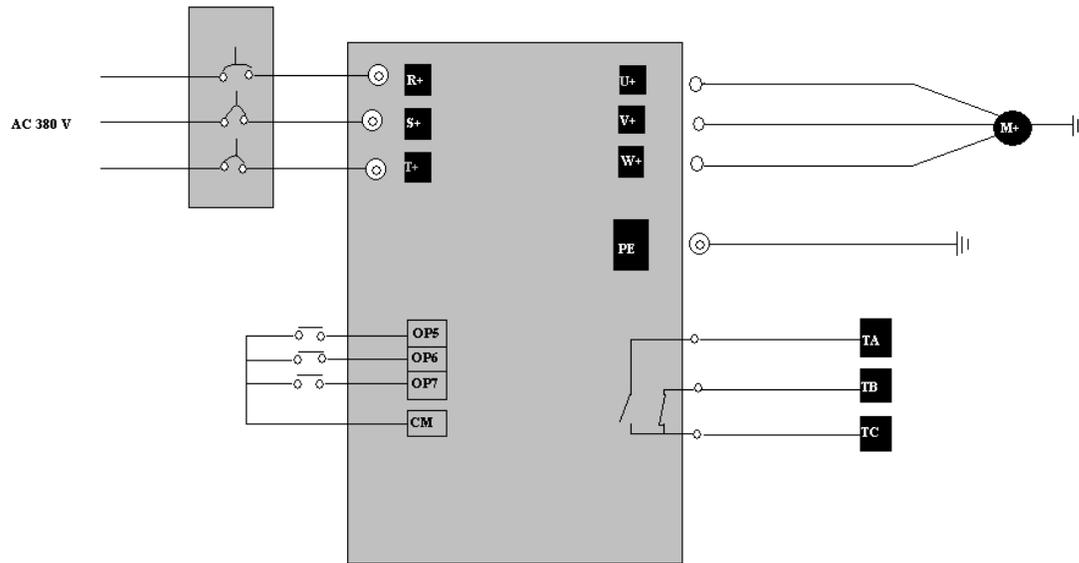


Fig 6: wiring diagram 2:

1. Connected the wires in accordance with the circuit diagram as above. After checking the wiring successfully VFD was powered on.
2. Entered the programming menu using “Mode” key.
3. Measured the functional parameters of the motor.
4. Entered F801 parameter and set the rated power of the motor to 2.2 kW.
5. Entered F802 parameter and set the rated voltage of the motor to 380 V.

6. Entered F803 parameter and set the rated current to the motor to 4.3 A.
7. Entered F804 parameter and set the number of poles of the motor to 2.
8. Entered F805 parameter and set rotary speed of the motor to 1440 rpm.
9. Entered F800 parameter and set it to 1 or 2 to allow measuring the parameter of the motor (1= running parameter mode, 2=static parameter mode. In the static parameter mode motor was supposed to be disconnected from load.).
10. Pressed “Run” key to measure the parameters of the motor. After completion of the measurement, the motor stopped running and relevant parameters were stored in F806-F809.
11. Set functional parameters of the VFD
12. Entered F106 parameter and set it to 0; selected sensor less vector control for the control mode.
13. Entered F203 parameter and set it to 0; selected the mode of frequency setting to digital given memory.
14. Entered F111 parameter and set it to 50.0 Hz.
15. Entered F208 parameter and set it to 1; select two line control mode 1.
16. Close switch OP6, the inverter starts forward running.
17. During running, current frequency was changed by pressing or

18. During running switched off the switch OP6, then close OP7, the running direction of the motor changed.
19. Switched off switched OP6 and OP7, motor decelerated and stopped.
20. Switched off the air switch and de-energize the inverter.

A tentative working diagram of a VFD system is given below:

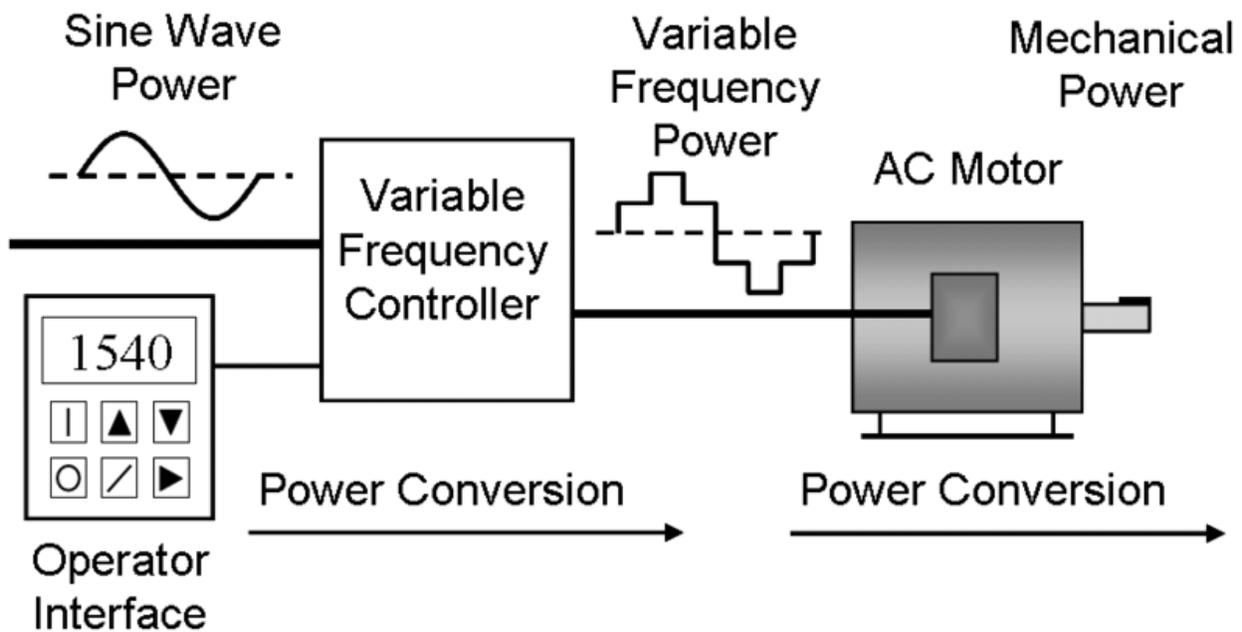


Fig 7: 9. A simple VFD system.

Reference: [http://en.wikipedia.org/wiki/Variable frequency drive](http://en.wikipedia.org/wiki/Variable_frequency_drive)

4.4: Gearbox

A gearbox or transmission provides speed and torque conversions from a rotating power source to another device using gear ratios. The most common use is in automobiles where the transmission adapts the output of the internal combustion engine to the drive wheels. Such engines need to operate at a relatively high rotational speed, which is inappropriate for starting, stopping, and slower travel. The transmission reduces the higher engine speed to the slower wheel speed, increasing torque in the process.

The gearbox used in the experiment is a 4-speed manual transmission automotive gearbox.

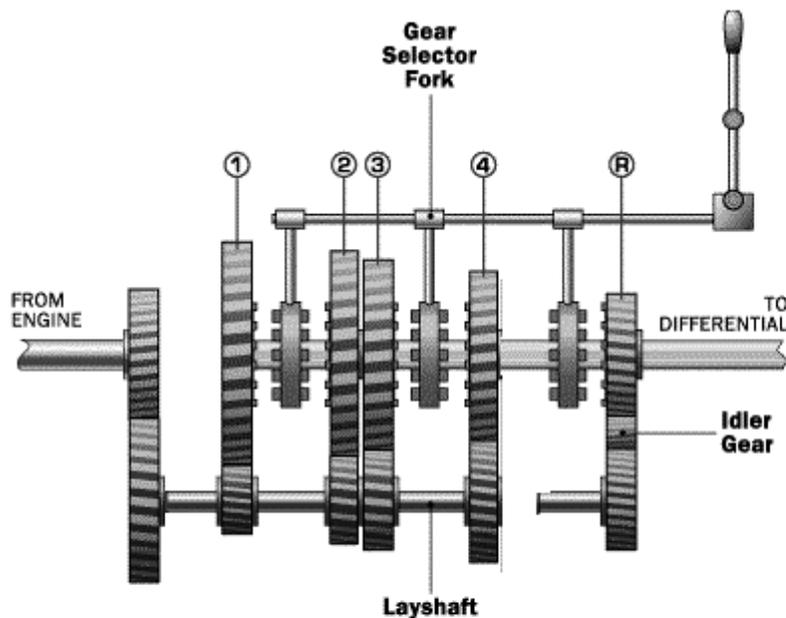


Fig 8: 4-speed manual transmission gearbox1

Reference: How stuff works

This 4-speed transmission applies one of four different gear ratios to the input shaft to produce a different rpm value at the output shaft. The shaft and the gears of the lay shaft shown in the above figure are connected as a single piece, so all the gears on the lay shaft and the lay shaft itself spins as one unit. The lay shaft receives power directly from the engine whenever the clutch is engaged. The shaft connecting to the differential contains 5 gears which freely rotate on it and 3 collars. The purpose of the collar is to get engaged to one of the gear so that the gear no longer rotates freely but along with the shaft. The power from the lay shaft is transmitted to the shaft connecting to the differential when the collar on the shaft is engaged to any of the five gears.

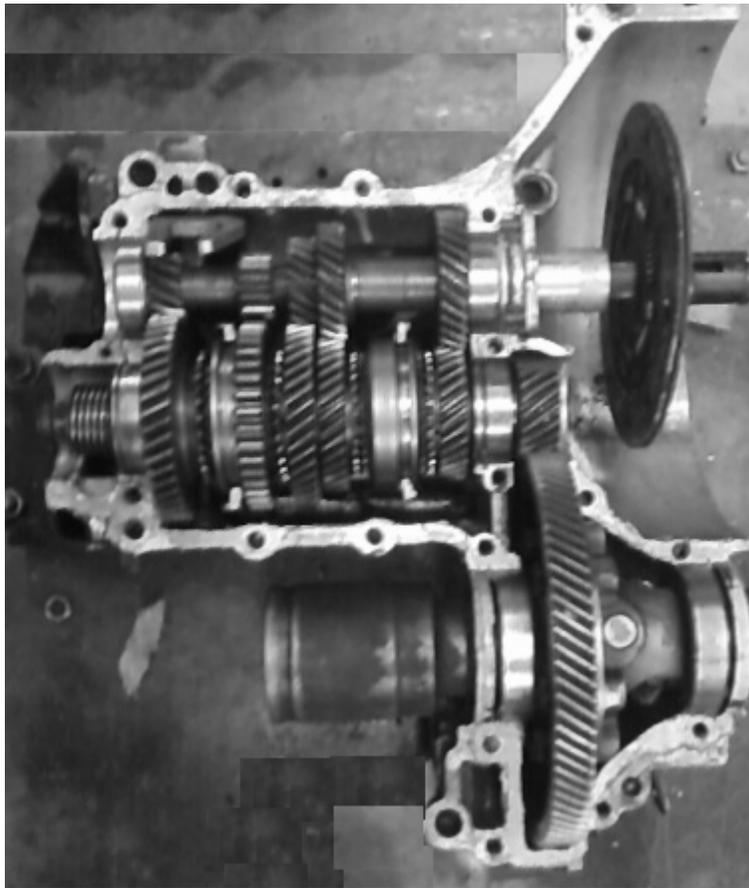


Fig 9: 4 speed manual transmission Gearbox2

In the experimental set up the rotation to the input shaft is given by the Induction motor, connected by two hook joints, and the load to the output shaft is given with the help of a magnetic brake.

4.5: Universal Hooke Joint:

A Universal joint, U joint, Cardan joint, Hardy-Spicer joint, or Hooke's joint is a joint in a rigid rod that allows the rod to 'bend' in any direction, and is commonly used in shafts that transmit rotary motion. It consists of a pair of hinges located close together, oriented at 90° to each other, connected by a cross shaft.

In the experiment we use a double hook joint transmit motion in the gearbox from the 3-phase induction motor. This configuration uses two universal joints by an intermediate shaft with the second universal joint phased in relation to the first to cancel the changing angular velocity. In this configuration the assembly will result in an almost constant velocity provided both the driving and the driven shaft are parallel and the two joints are correctly aligned to each other.



Fig 10: Universal Double hook joint

4.6: Magnetic Brake

Magnetic brakes are a relatively new technology that is beginning to gain popularity due to their high degree of safety. Rather than slowing a component via friction, magnetic brakes rely completely on certain magnetic properties and resistance. In fact, magnetic brakes never come in contact with the component.

Magnetic brakes are made up of one or two rows of very strong neodymium magnets. When a metal fin (typically copper or a copper/aluminum alloy) passes between the rows of magnets, eddy currents are generated in the fin, which creates a magnetic field opposing the fin's motion. The resultant braking force is directly proportional to the speed at which the fin is moving through the brake element. Magnetic brakes are also completely silent and are much smoother than friction brakes.

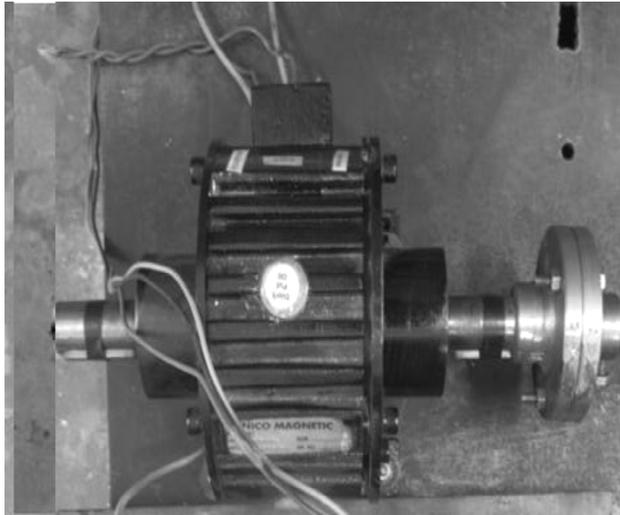


Fig 11: Magnetic Brake with connection to Variac.

4.7: Flange coupling

Flange coupling is a coupling used to connect two rotating shafts of different diameters. It consists of flanges or half couplings, one of which is fixed at the end of each shaft. The two flanges are bolted together with a ring of bolts to complete the drive. There are two flange couplings used in the experiment.



Fig 12: Flange coupling.

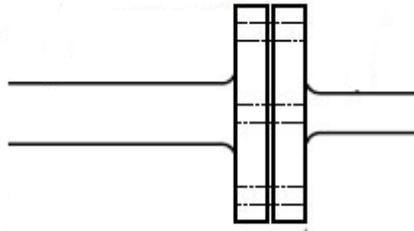


Fig 13: side view of a flange coupling.

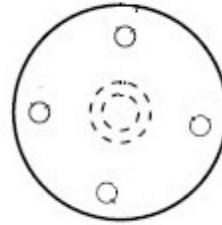


Fig 14: Front view.

Reference: MATHalina.com

Flange coupling usually applies to a coupling having two separate cast iron flanges. Each flange is mounted on the shaft end and keyed to it. The faces are turned up at right angle to the axis of the shaft. One of the flanges has a projected portion and the other flange has a corresponding recess. This helps to bring the shafts into line and to maintain alignment. The two flanges are coupled together by means of bolts and nuts. The flange coupling is adapted to heavy loads and hence it is used on large shafting. The flange couplings are of the following types:-

4.8:a) Unprotected type flange coupling

4.8:b) Protected type flange coupling

4.8:c) Marine type flange coupling

a) Unprotected type flange coupling:- In an unprotected type flange coupling each shaft is keyed to the boss of a flange with a counter sunk key, and the flange are coupled together by means of bolts. Generally, three, four or six bolts are used. The keys are staggered at right angle along the

circumference of the shafts in order to divide the weakening effect caused by key ways.

b) Protected type flange coupling:- In a protected type flange coupling the protruding bolts and nuts are protected by flanges on the two halves of the coupling, in order to avoid danger to the workman.

c) Marine type flange coupling: - In a marine type flange coupling, the flanges are forged integral with the shafts. The flanges are held together by means of tapered headless bolts numbering from four to twelve depending upon the diameter of shaft.

4.8: Clutch plate

Clutches are useful in devices that have two rotating shafts. In these devices, one of the shafts is typically driven by a motor or pulley, and the other shaft drives another device. The clutch connects the two shafts so that they can either be locked together and spin at the same speed, or be decoupled and spin at different speeds. The clutch used in this experiment was for connecting the universal joint to the gearbox using arc welding operation.

4.9: Current probe:



Fig 15: AC current probe.

Fluke Current clamps are the ideal tools to extend the current ranges of Multimeters.

- * Companion to a DMM to measure up to 200 A AC
- * 1mA per Amp output guarantees easy reading on you meter
- * Take accurate current readings without breaking the circuit.

Specifications:

| | |
|----------------------------------|--------------------------|
| Nominal current range: | 200 A |
| Continuous current range: | 0.5 A - 200 A |
| Maximum Non-Destructive Current: | 240 A |
| Lowest measurable current: | 0.5 A |
| Basic Accuracy : | 1% + 0.5 A (48-65 Hz) |

| | |
|--------------------|-------------------------|
| | (% reading + floorspec) |
| Useable frequency: | 40 Hz - 10 kHz |
| Output level(s): | 1 mA/A |

4.10: Multimeter

A multimeter or a multimeter, also known as a volt/ohm meter or VOM, is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter may include features such as the ability to measure voltage, current and resistance. There are two categories of multimeters, analog multimeters and digital multimeters (often abbreviated DMM or DVOM.)



Fig 16: Multimeter.

4.11: Spirit level

A **spirit level** or **bubble level** is an instrument designed to indicate whether a surface is level or plumb. Different types of spirit levels are used by carpenters, stone masons, bricklayers, other building trades workers, surveyors, millwrights and other metalworkers, and serious videographers.

Some are also capable of indicating the level of a surface between horizontal and vertical to the nearest degree. The most sophisticated spirit levels are guaranteed accurate to five-ten-thousandth of an inch (.0005) per inch and are much easier to read because of their green/yellow color.

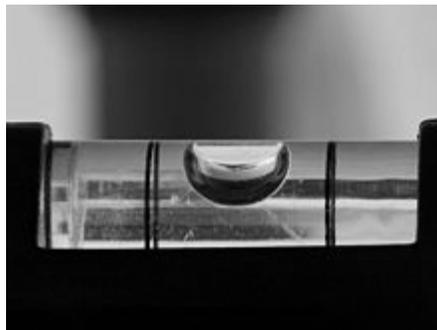


Fig 17: spirit level

4.12: Tachometer

A tachometer (also called a revolution-counter, rev-counter, or RPM gauge) is an instrument that measures the rotation speed of a shaft or disk, as in a motor or other machine. The device usually

displays the revolutions per minute (RPM) on a calibrated analogue dial, but digital displays are increasingly common.

5.

FABRICATION

The setup was placed on a Cast iron rectangular block. Induction motor, magnetic brake and the gearbox were bolted on the rectangular block. Channel was used for placing the 3-phase induction motor so that the motor and the gearbox are properly aligned with each other. Additional rectangular plates were welded on the rectangular block and fastened to the gearbox so that the gearbox is fixed completely and does not vibrate during high rotational speeds. Two flange couplings were fabricated for connecting

- Induction motor to one end of the Universal joint.
- Magnetic brake to one of the drive axles.

The two universal joints were connected to each other and one end of the double joint was then inserted and bolted in the flange coupling. The other end of the universal joint was connected to the input shaft of the gearbox by with the help of a clutch plate. The end of the joint was welded to the clutch plate which in turn was placed on the input shaft of the gearbox. Here the operation was carried in the welding shop using Arc welding. At first a small couple of diameter exactly equal to the end of double joint was welded to the clutch plate. Then the double joint was inserted in the couple and was welded.

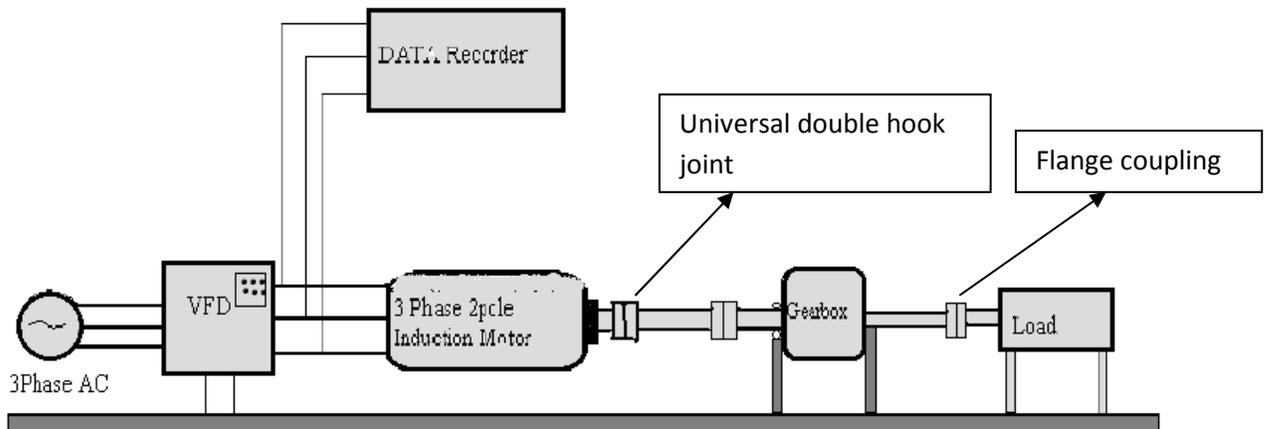


Fig 18: Schematic Diagram of the Experimental setup.

The drive axles were connected to the gearbox and one of the axles was connected to the magnetic brake with the help of a flange coupling. The magnetic brake acts as a load due to which different gear ratios can be employed in the gearbox. For arresting the rotation of the other axle a clamp was made and fixed on the axle.

For varying the input voltage to the magnetic brake, a variac was connected to it. The voltage available at the magnetic brake was checked with the help of a multimeter. Also the variable frequency drive was connected to the induction motor for varying the input frequency.



Fig 19: universal joint shaft welded to clutch plate.

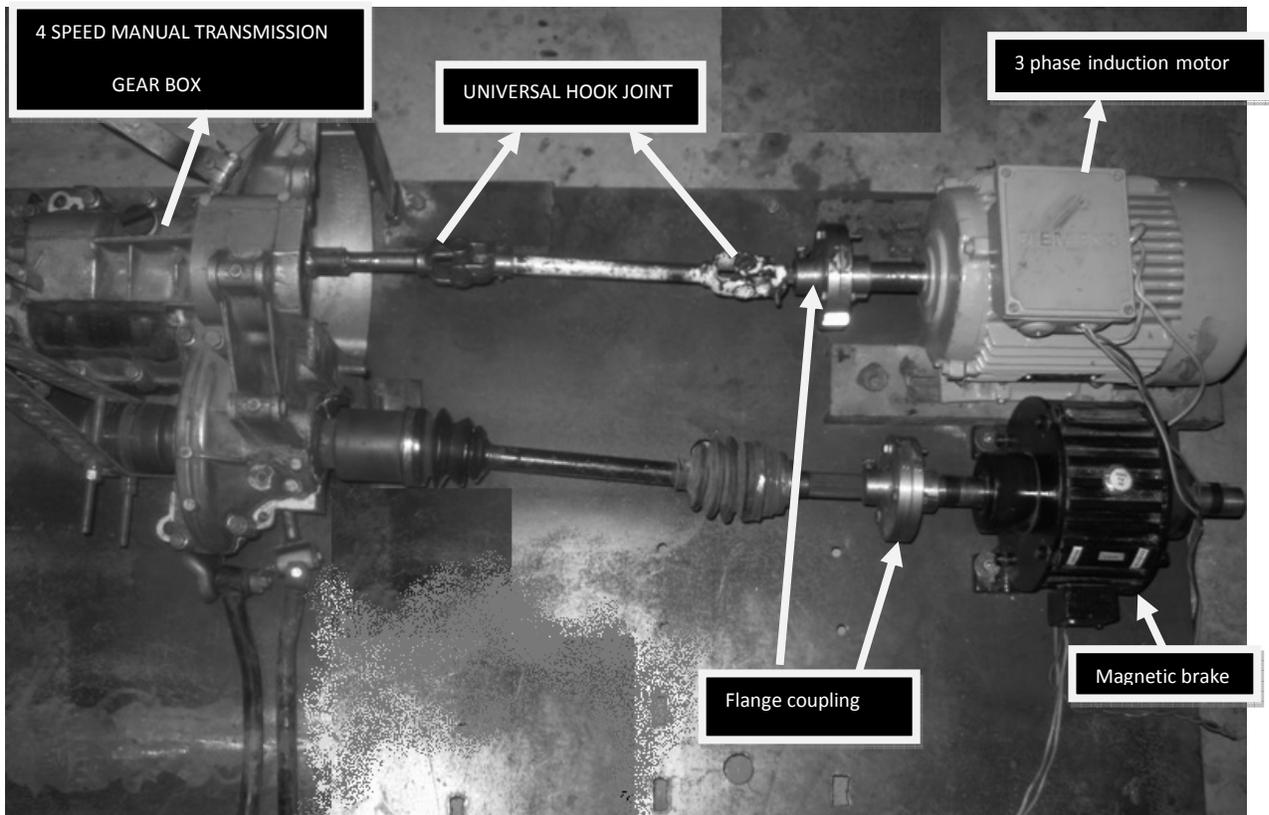


Fig 20: the Final fabricated set-up.

6. RESULTS AND DISCUSSION

The basic aim of the experimentation was to design the arrangement in order to predict the gear ratio of the gearbox and to get the motor current signature of the input motor. For this the arrangement was done and the motor was made to run in various RPM which was controlled by the Variable Frequency Drive (VFD). Load was given to the gearbox with the help of the help of the magnetic brake by setting the input voltage with help of a Variac to 16 volts.

The motor was run on three different speeds at 500, 1000 and 2000 RPM respectively and the speed of the driven shaft was measured using a Tachometer. 4 such readings were taken each for the 4 different gears. The results of the run are given in the table below:

For the 1st gear:

TABLE 1:

| Serial NO: | Gear no. | Speed of the driving shaft as on VFD. (RPM). | Speed of the driven shaft shown by tachometer(RPM) | Gear ratio. | Overall gear-ratio |
|------------|----------------------|--|--|-------------|--------------------|
| 1. | 1 st gear | 500 | 63.9 | 7.824 | 7.84:1 |
| | | | 64.1 | 7.801 | |
| 2. | | 1000 | 127.8 | 7.824 | |
| | | | 127.8 | 7.824 | |
| 3. | | 2000 | 254.8 | 7.849 | |
| | | | 254.7 | 7.853 | |

Similarly for the second gear the speed of the driven shaft are:

TABLE 2:

| Serial NO: | Gear no. | Speed of the driving shaft as on VFD. (RPM). | Speed of the driven shaft shown by tachometer(RPM) | Gear ratio. | Overall gear-ratio |
|------------|----------------------|--|--|-------------|--------------------|
| 1. | 2 nd gear | 500 | 106 | 4.716 | 4.71:1 |
| | | | 106.2 | 4.708 | |
| 1000 | | 212 | 4.716 | | |
| | | 211.9 | 4.719 | | |
| 3. | | 2000 | 424.8 | 4.708 | |
| | | | 424.8 | 4.708 | |

For the 3rd gear:

TABLE 3:

| Serial NO: | Gear no. | Speed of the driving shaft as on VFD. (RPM). | Speed of the driven shaft shown by tachometer(RPM) | Gear ratio. | Overall gear-ratio |
|------------|----------------------|--|--|-------------|--------------------|
| 1. | 3 rd gear | 500 | 173.5 | 2.881 | 2.90:1 |
| | | | 173.3 | 2.881 | |
| 1000 | | 344.3 | 2.904 | | |
| | | 344.3 | 2.904 | | |

| | | | | | |
|----|--|------|-------|-------|--|
| 3. | | 2000 | 689.6 | 2.900 | |
| | | | 689.6 | 2.900 | |

For the 4th gear:

TABLE 4:

| Serial NO: | Gear no. | Speed of the driving shaft as on VFD. (RPM). | Speed of the driven shaft shown by tachometer(RPM) | Gear ratio. | Overall gear-ratio |
|------------|----------|--|--|-------------|--------------------|
| 1. | 4th gear | 500 | 255 | 1.960 | 1.96:1 |
| | | | 255.1 | 1.960 | |
| 2. | | 1000 | 510 | 1.960 | |
| | | | 510 | 1.960 | |
| 3. | | 2000 | 1019 | 1.962 | |
| | | | 1019 | 1.962 | |

So the overall gear ratio for the 4 speed manual transmission gearbox is:

1st gear: 7.84:1

2nd gear: 4.71:1

3rd gear: 2.90:1

4th gear: 1.96:1

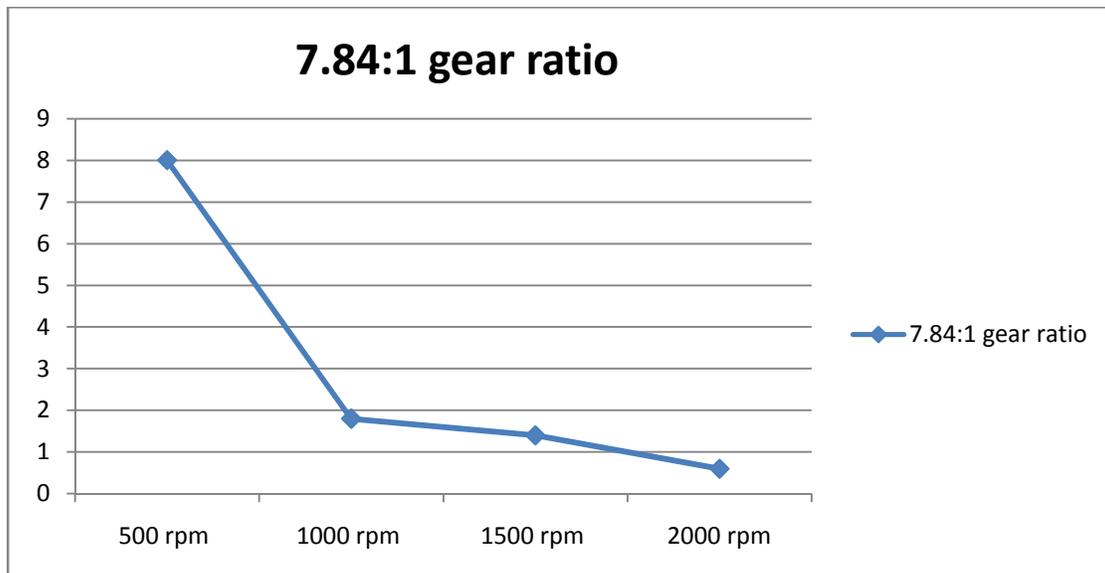
After finding out the gear ratios the input current of the induction motor was found with the help of a Current Probe. For this one of the phases was selected and Current probe was clamped around it and the readings were taken with the help of a multimeter.

The readings were as follows:

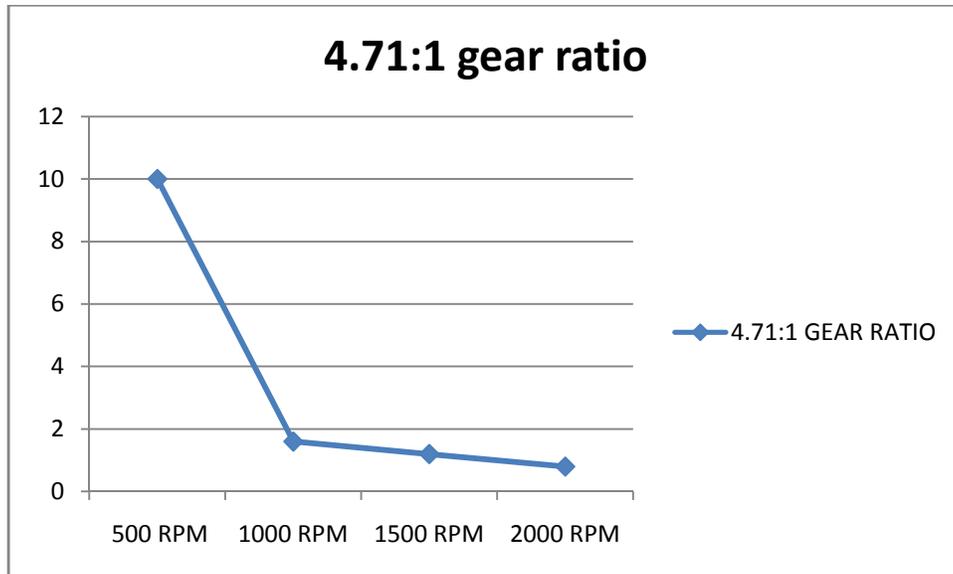
TABLE 5:

| Gear. | Speed of the driving shaft (RPM) | Current(Amp) |
|-----------------------|----------------------------------|--------------|
| 1 st gear. | 500 | 8.0 |
| | 1000 | 1.8 |
| | 1500 | 1.4 |
| | 2000 | 0.6 |
| 2 nd gear. | 500 | 10.0 |
| | 1000 | 1.6 |
| | 1500 | 1.2 |
| | 2000 | 0.8 |
| 3 rd gear. | 500 | 9.4 |
| | 1000 | 1.6 |
| | 1500 | 1.1 |
| | 2000 | 0.8 |
| 4 th gear. | 500 | 10 |
| | 1000 | 1.4 |
| | 1500 | 1.1 |
| | 2000 | 0.6 |

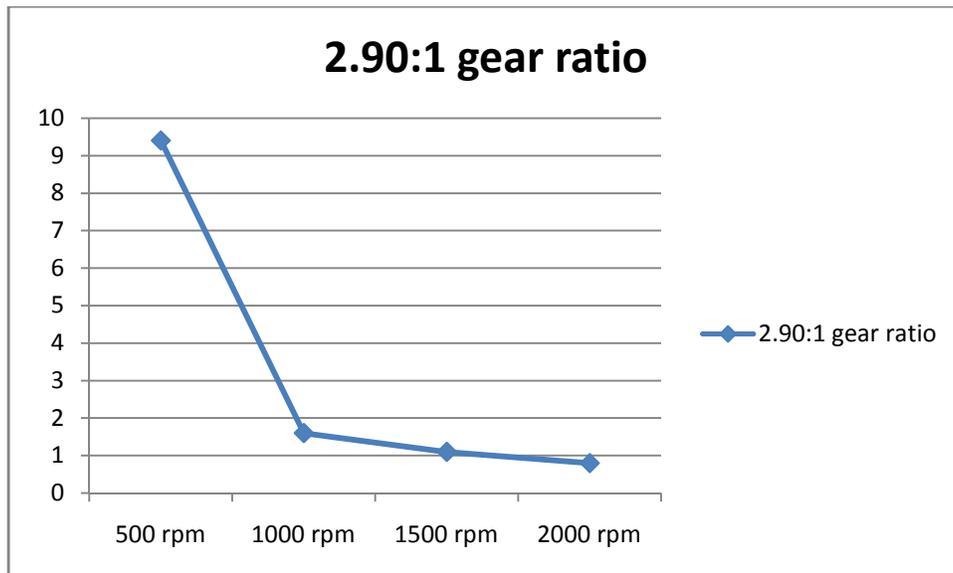
From the data collected of the current flow to the motor with the changing speed of motor, graphs are plotted with current vs. RPM of the driving shaft. With current at the y axis and speed of the motor in the X axis 4 different graphs are plotted.



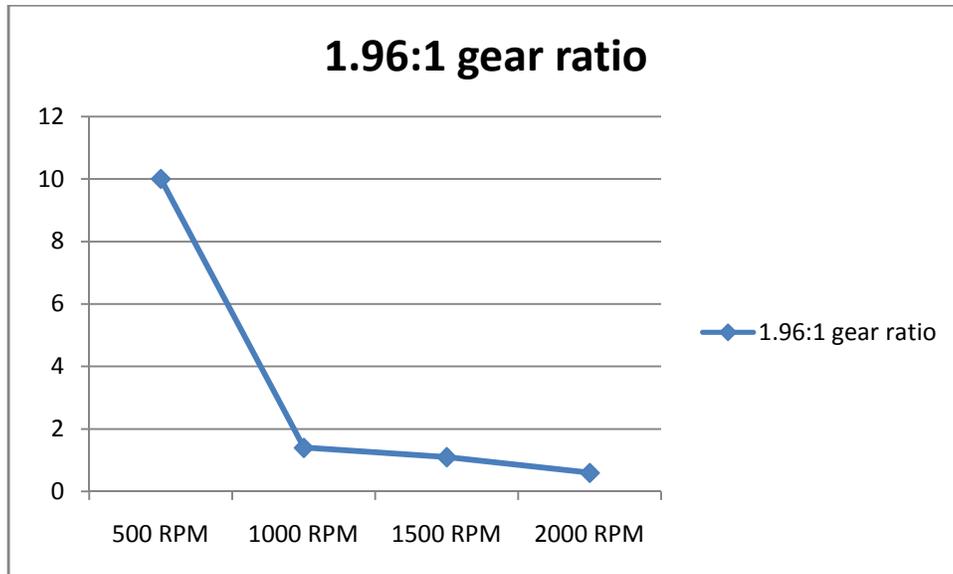
GRAPH 1: Motor current Vs. motor speed for 7.84:1 gear ratio:



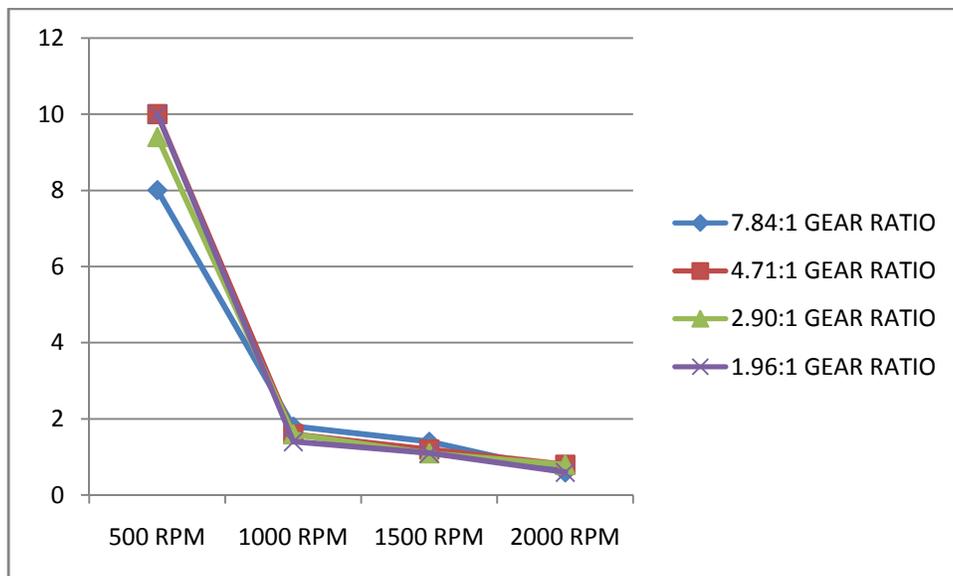
GRAPH 2: Motor current Vs. motor speed for 4.71:1 gear ratio.



GRAPH 3: Motor current Vs. motor speed for 2.90:1 gear ratio.



GRAPH 4: Motor current Vs. motor speed for 1.96:1 gear ratio.



GRAPH 5: Motor current Vs. motor speed various gear ratio.

- It has been found that the motor current decreases with increasing input speed of gearbox. For low rpm of the input shaft the current withdrawn by the induction motor is maximum and minimum for high rpm of the input shaft.
- The decreasing motor current with increasing input speed is due to the fact that as the rpm increases the torque value decreases and so the current withdrawn by the induction motor.
- For different gear ratios the plot of motor current vs input speed remains almost same.
- This plot can be taken as a standard for measuring defects in gearboxes. Any deviation from this plot means there is some defect in the gearbox which is tested. For example, if there is any misalignment of the gears, or any gear tooth is broken then there is sudden upsurge in the current withdrawn by the induction motor.

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