Design of a mobile reciprocating pumping system for platinum mines (…pneumatically powered) (CASE FOR ZIMBABWE).

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Abstract

Like most other developing countries, mining remains the soul of Zimbabwe's economy. The drilling and mining equipment operation is based on hydraulics. The steering system, the hoisting, dumping, hauling and hydraulics systems constitutes approximately 80% of the mechanical build-up of these equipment. In a mining setup, lubrication of the hydraulic system for these equipment is extremely critical. Breakdown of these machines may lead to the need of refilling of the hydraulic tanks hence a convenient mobile pumping system has become the crying need for mining industries. Literature was carried out on already existing designs. Information obtained includes, materials used, methods used, selected operating mechanisms, history of designs from various sources. Information pertaining to the parts regarding price, rating, availability, functions, performance and alternatives was obtained. In the design process, the reciprocating aspect of the slider crank was designed basing on the discharge flow required. An experiment was carried out to determine the flowrate. A diaphragm was added to the piston to ensure the separation of the oil being pumped and the actuator(pneumatics). Pneumatics offers a more flexible safer alternative to electric motors. Air is clean and will not harm to the environment in case of any leaks. There is also reduced risk of ignition as there will be no magnetic fields or sparks associated with the system. The von Mises stresses and deflections were done using Solidworks and they were in range and the weakest point was determined. The bending stresses were performed using SkyCiv Software. Design specifications and drawings were developed for the machine. Specifications for the manufacture and assembly of the mobile reciprocating pumping system was also provided. House of quality was carried out focusing on reduction of cost through minimizing the number of parts retaining its function. Material for components were selected.

Keywords
Design, pneumatically powered, mobile, Zimbabwe

1. Introduction

Like most other developing countries, mining remains the soul of Zimbabwe's economy. The drilling and mining equipment operation is based on hydraulics. The steering system, the hoisting, dumping, hauling and hydraulics systems constitutes approximately 80% of the mechanical build-up of these equipment. In a mining setup, lubrication of the hydraulic system for these equipment is extremely critical. Hydraulics can fail anytime and anywhere! Breakdown of these machines may lead to the need of refilling of the hydraulic tanks hence a convenient mobile pumping system has become the crying need for mining industries.

Figure 1. LHD hauling platinum from mine blast

1.1 Background

After a couple of years from the shadoof invention, all the chief pumping systems' designs had been presented and mostly advanced into marketable products(RSS, 2008). When the reciprocating pumps were invented they were hand operated, like the bicycle pump. As time went on, it was discovered that the same mechanism could be used in larger industries for heavy duty pumping. Now, this meant the systems needed to be designed with driving mechanisms to shift from the mechanical systems relied upon before.

With technological advancements, inventions moved from the hand operated to the electrical powered. The need for environment security called for the new invention of pneumatic driven pumping systems.

1.2 Problem statement

Transportation of machinery from breakdown point (underground) to workshop (surface) for refilling of hydraulic oil increases downtime and maintenance costs thus having a negative impact on production.

Figure 2. Man using a fixed system

1.3 Aim of the research paper

- Design for manufacture and assembly of a mobile reciprocating pumping system for refilling of TMM (trackless mobile machinery) hydraulic oil tanks during breakdown**.**

1.4 Objectives

- to design a system that can be transported by the utility vehicles in the mine
- to design a pneumatically powered system
- to design a system that can be engaged and dis-engaged from an external oil tank

1.5 Justification

Air is clean and therefore there will be no harm to the environment in case of any leaks. There is also reduced risk of ignition as there will be no magnetic fields or sparks associated with the system.

1.5.1 Variation of pressure

The delivered pressure is high and also there is continuous rate of delivery due the pressure controlled valves. Moreover, it can work in a wide range of pressure, enabling the application of the required certain amount of oil(E.MOLLOY, 1941)

1.5.2 Reliability and convenience

Storage of compressed gas enables the perpetual running of machinery after electric power has been cut(Parr, 1998). Since the system is mobile, it can be readily transported to the point of need without having to tram the heavy machinery to surface risking failure of more components.

1.5.3 Less costly

It provides a lower cost since air is a cheap resource.

1.5.4 Reduced downtime

The process of towing the heavy mining machinery from underground to surface, increases downtime and hence educes availability negatively impacting on productivity. The proposed system will reduce downtime as it can be conveniently transported to the point of breakdown for refilling purposes.

2. Literature review

2.1 Main components of a reciprocating pump

It comprises of a crank, Connecting rod, Cylinder, Suction pipe, Suction valve, Delivery pipe, Delivery valve, Strainer and Air vessel. This is found in figure 3 below

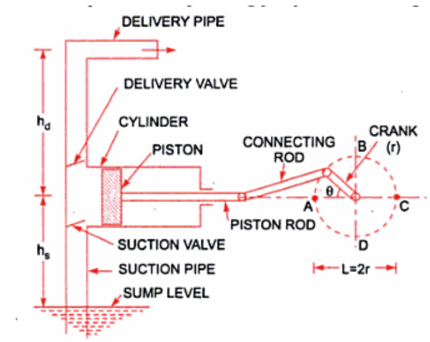

Figure 3. Components of a reciprocating pump

2.2 Working principal of the reciprocating pump

It basically works on the idea of an Internal Combustion (IC) engine.

2.3 Actuators

These are muscles that gives power to a system. There are four main types of actuators namely Hydraulic, Pneumatic, Electric and Mechanical selected on the size of the machine. Hydraulic actuators are normally used on big machines.

2.3.1 Pneumatic actuators

Pneumatic Transmission of Energy: Pneumatic actuators use compressed gas. For a pneumatic system, compressed gas is stored which possesses potential energy. When the compressed gas expands, the potential energy translates to kinetic energy which is regarded as the working energy of the system. With the opening of the outlet valve, the air expands until it equals the atmospheric pressure. A reciprocating compressor is then needed to translate the energy which the air possesses into workable energy at a desired pressure.

Regulation of Pneumatic Energy: Energy possessed by pneumatics needs proper regulation to ensure that the efficiency is not compromised and that substantial damage is not done to the machinery or operators handling it. Controlling of pneumatic energy can be achieve through the use valves.

Regulation of Pressure: Regulation of pressure is done at two points, first which is after it passes the compressor to protect the system and secondly when it is past the pneumatic receiver tank to ensure a stable and steady actuator pressure.

Pressure regulation after the Compressor: Usually the energy delivered by a compressor is not used instantly. A pneumatic receiver tank stores the compressed gas under potential energy. A compressor is run during its air delivery and shut when high pressure is achieved. When air pressure in the receiver tank falls below the required the compressor kicks in and recharges it. A common way of detecting the pressure drops is through a control switch.

Safety Relief Valve: Pneumatic system operation involves high pressures which are of cause regulated by a control system. In case the control system fails, a valve is put in place to protect the machinery from substantial damage known as the safety relief valve. A safety relief valve is not designed for frequent operation. Typical safety relief valves have alert mechanisms in the case of an emergency such as whistles and horns (D, 2001).

3. Methodology

3.1 Softwares

Multiples software were used for simulation and analysis of behavior of the design under working loads to determine how safe the design is. SolidWorks was used for 3D models, assembly of parts, stress and strain analysis. The bending stresses were performed using SkyCiv Software.

3.3 Experiment

An experiment was carried out for a desired flow rate to determine the diameters of the piping system as well as the performance of the pump.

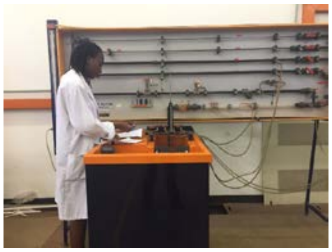

Figure 4. Laboratory experiment

4. Results and discussion

4.1 Dual piston-diaphragm pump

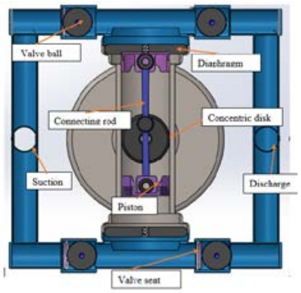

Figure 5. How the system looks like

4.2 Stress analysis

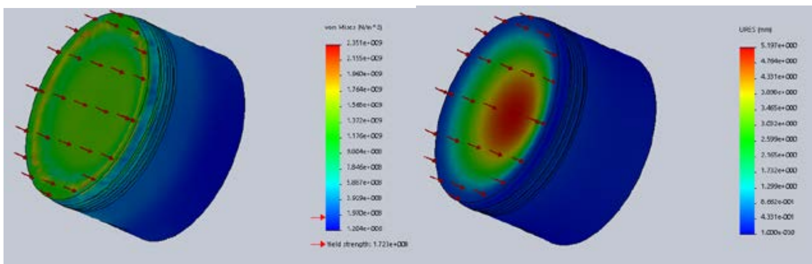

Figure 6. a.) Piston Von misses stresses, b.) Piston displacement analysis

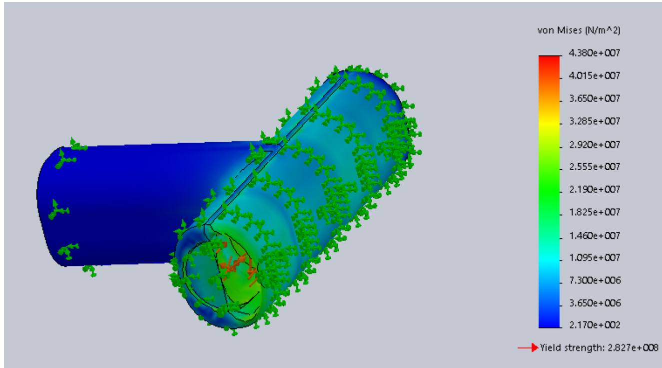

Figure 3. Von misses stresses for the cylinder block

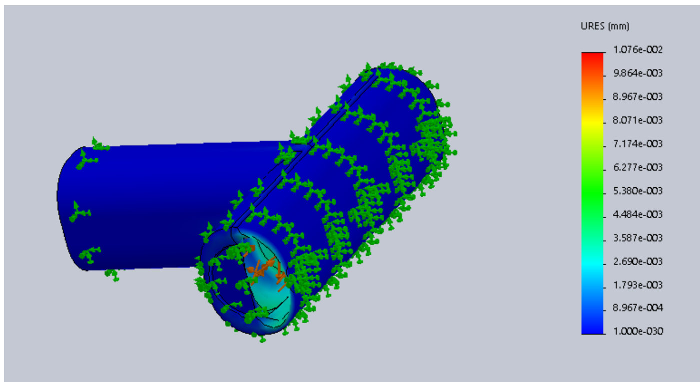

Figure 4. Displacement for the cylinder block

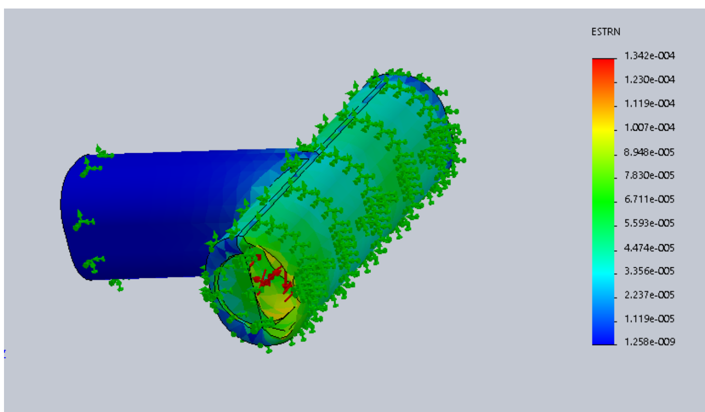

Figure 5. Strain for the cylinder

Figure 6.Ball valve

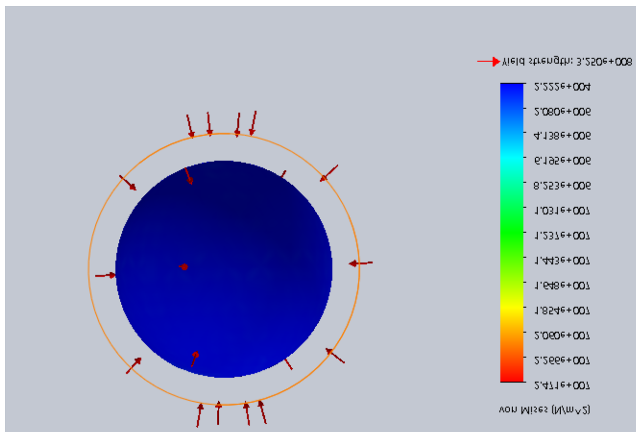

Figure 7.Ball valve von misses analysis

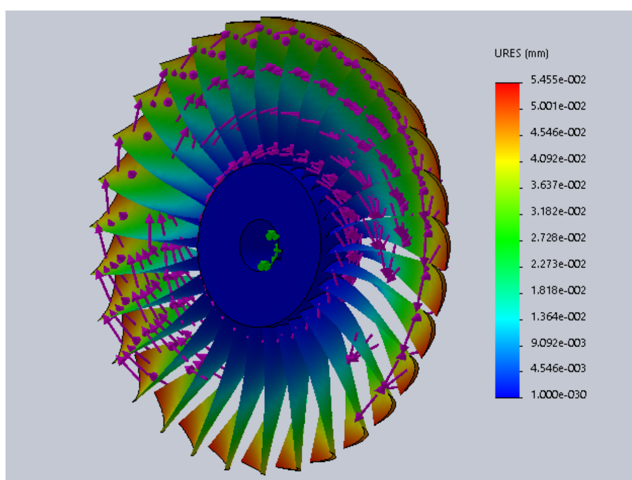

Figure 8. Fan displacement forces analysis

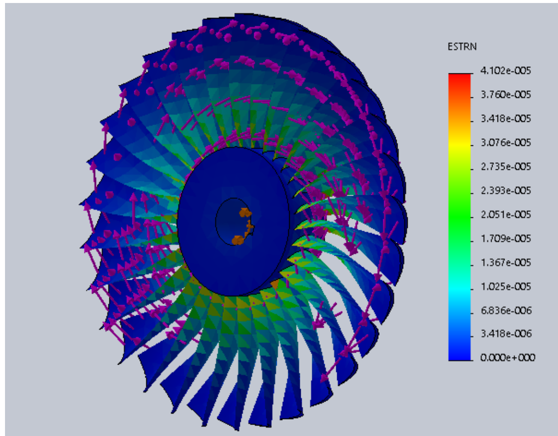

Figure 9. Fan displacement forces analysis

4.3 Bending moments

Concentric disk and fan shaft

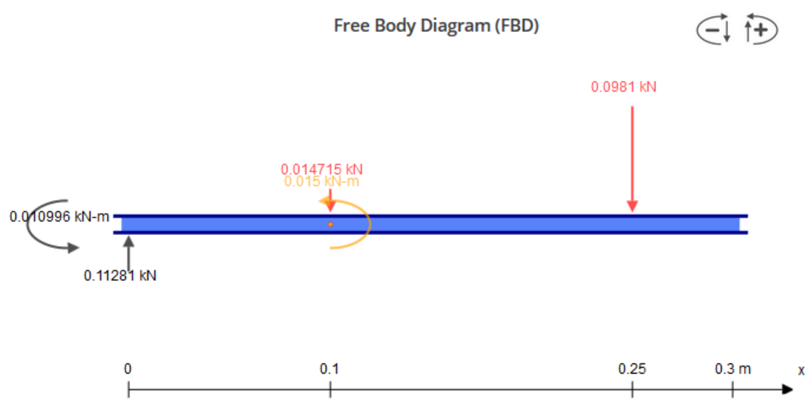

Figure 10. Bending moment for shaft

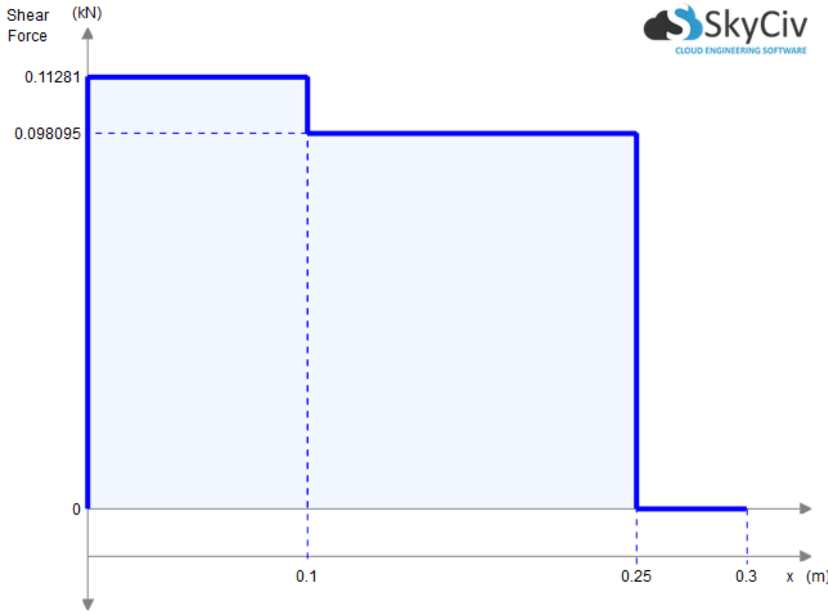

Figure 11. Shear force diagram

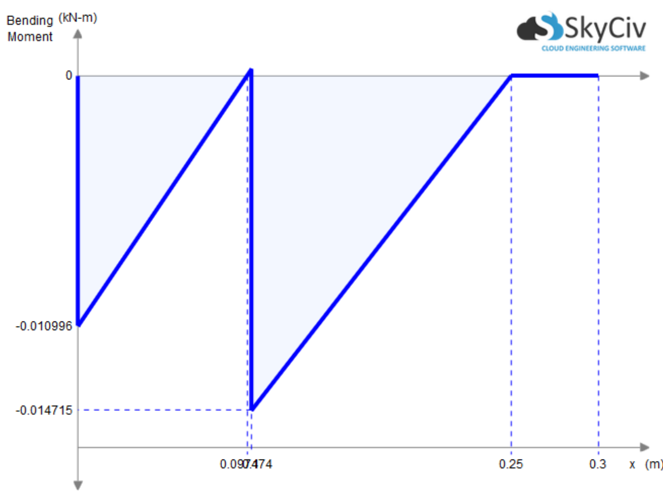

Figure 12. Bending moment diagram

For the trolley

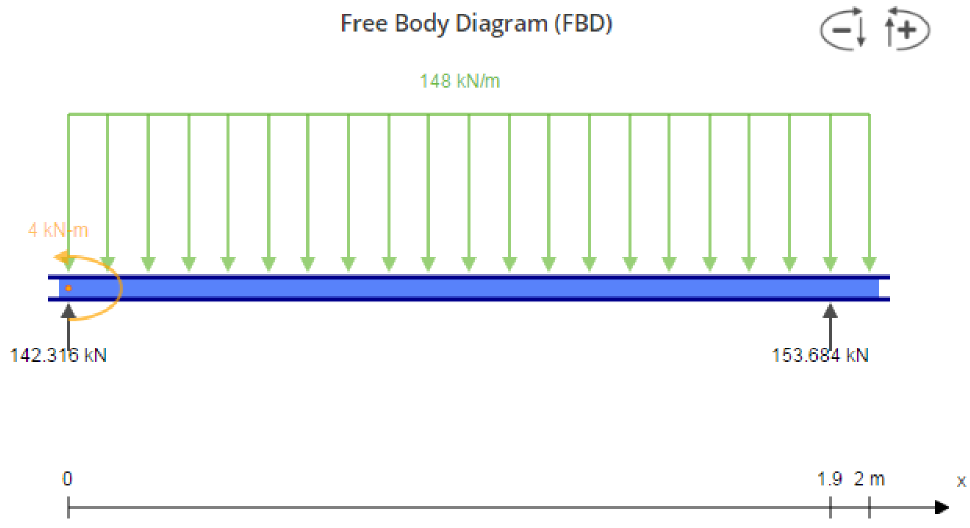

Figure 13.Loading for the trolley

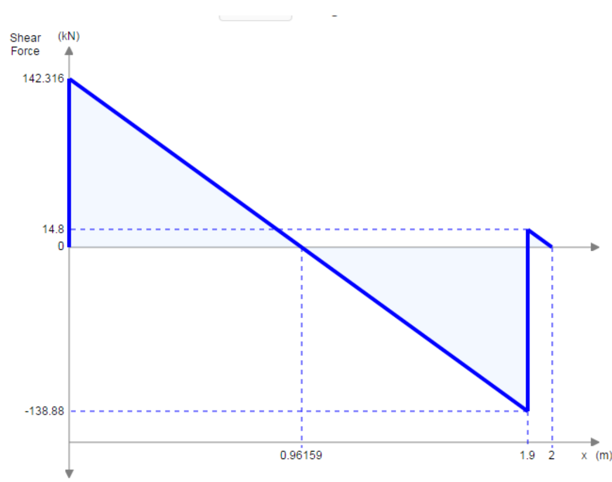

Figure 14. Shear force diagram

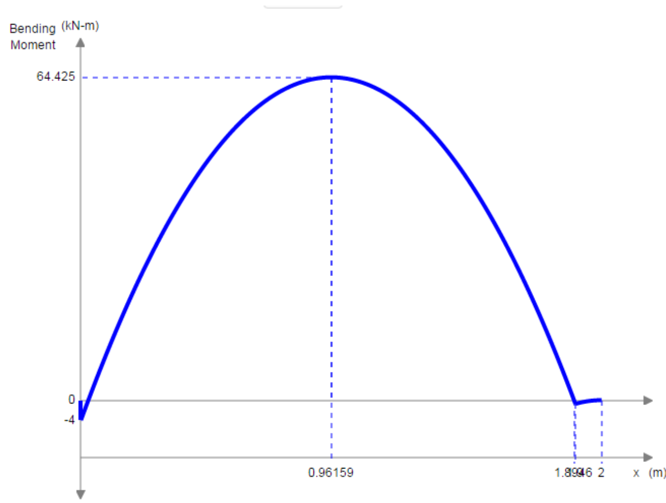

Figure 15. Bending moment diagram

4.4 Pumping system assembly

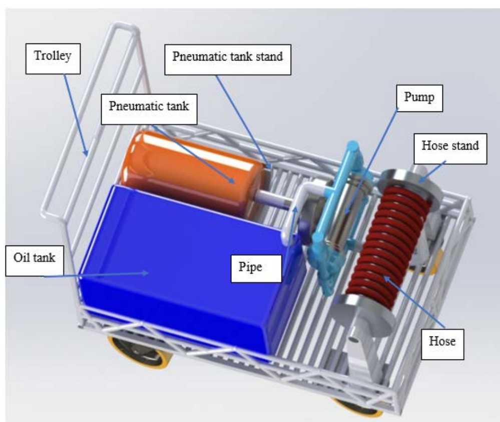

Figure 16. Trolley assembly 3D

The design is safe for the working conditions designed for.

5. Recommendations

Reciprocating pumps, still however have challenge of wearing out. Condition monitoring could be applied to predict failure so as to prevent catastrophic failure. As it has still a couple of moving parts, failure of one component can affect e whole system and functionality which will be very expensive to repair.

6. Conclusion

As humans, we owe it to the environment to maintain a healthy and safe working place. As a company seeking to make profit we should see to it that we minimise cost as much as possible. Under these circumstances of downtimes threatening productivity a mobile pumping system can play a significant role. Mobile reciprocating pumping offers a convenient and safe way of delivering hydraulic oil into the drilling and trucking equipment hydraulic tanks. This mobile reciprocating pumping system was designed with an adjustable height mechanism which caters for the difference in height of operators. Tall people can operate it with ease without having to strain their backs and the same with short persons without difficulty. The research was a success as all objectives were addressed. This research will go a long way in offering a convenient platform for pumping and hence an increase in production giving our economy a dive over the current status.

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Authors Biographies

Martha Simbisai Ganyani was born in Zvishavane, Zimbabwe in 1995. She is currently a student at the University of Zimbabwe, Harare, studying for a Bachelor of Science Honors Degree in Mechanical Engineering. She did her Advanced and Ordinary level studies at Guinea Fowl High School in the Midlands province. In 2016, she joined the Zimbabwe Institute of Engineers as a student member. Her current research involves Robotics, Dynamics, Solid Mechanics and Finite Element Analysis.

Dr. Tawanda Mushiri received his Bachelor of Science Honors Degree in Mechanical Engineering (2004-2008) and a Masters (2011-2012) from the University of Zimbabwe, Harare, and a Ph.D. from the University of Johannesburg, South Africa (2013-2017). He also obtained a Certificate with Siemens in Programmable Logic Controllers in the year 2013 where he worked with SCADA and Link Programming. His doctorate involved fuzzy logic and automated machinery monitoring and control. Currently, he is a lecturer and Senior Research Associate at the university of Zimbabwe and University of Johannesburg, respectively. In the past (2012-2013), he has also lectured at the Chinhoyi University of Technology, Zimbabwe, lecturing mechatronics courses. He has also been an assistant lecturer for undergraduate students at Chinhoyi University of Technology, tutoring advanced manufacturing technology and machine mechanisms.

Professor Charles Mbohwa is an NRF-rated established researcher and professor in the field of sustainability engineering and energy focusing on green technology, energy and systems. In January 2012 he was confirmed as an established researcher making significant contribution to the developing fields of sustainability and life cycle assessment. He has contributed a chapter to a state-of-the-art book by experts in energy efficiency. In addition he has produced high quality body of research work on Southern Africa. Since 2012 he has worked on sustainability engineering with emphasis on integration of other soft aspects like humanitarian logistics and health care systems. The work also encompasses and integrates energy systems, life cycle assessment and bio-energy/fuel feasibility and renewable energy.