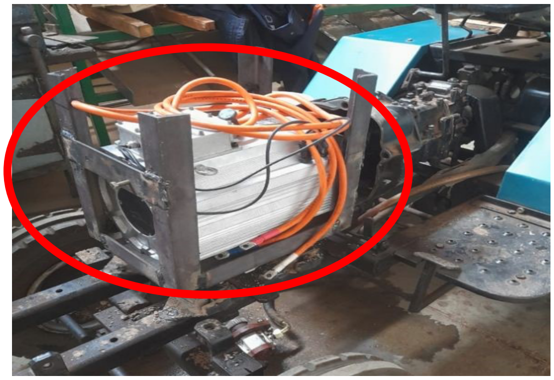
JIBEBE SHUJAA E-TRACTOR Mechanical team

Upgrade of ***Shujaa Tractor***

Internal combustion



Electric

Objective: Electrification of Shujaa tractor

Specific objectives

1. Disassembly of IC engine and its components
2. Design of motor and battery mountings
3. Design of a new steering system
4. Adjustments to increase **stability**
5. Fabrication and assembly of the EV

Specification of mechanical components

1. Motor coupling

   Made of treated mild steel with the following specifications:

Density	8000

Melting Point	1370-1400°c
Modulus of Elasticity	190-210 GPa
Electrical Resistivity	0.7 μΩm

- **POWERTRAIN**

The manual gearbox and clutch system was retained to shorten the time of development.

- **MOTOR MOUNTING**
    - Fabricated with focus on **cooling** capabilities and **weights reduction** and was made of mild steel angle bars and a 10mm plate.
      The motor mount was fixed to the chassis using rubber mounts so as to dampen the motor vibrations.

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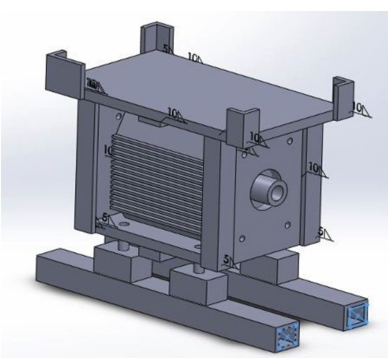
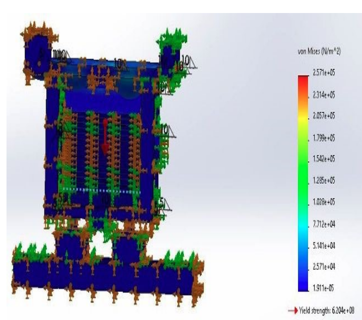


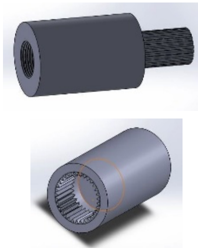


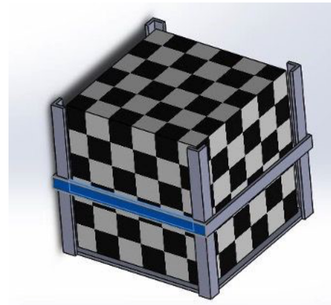
Simulation

Motor mount CAD

Design

Fabricated and upgraded components



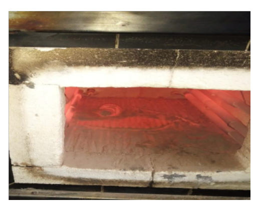



Couplings   Battery mount

Heat treatment of the mechanical parts

- Coupling for power transmission
    - **Mild steel** used
    - **Heat treated** to enhance the strength with assistance from ***Furnace***

Part (red-hot) Mr. Mwai


MILD STEEL HARDENING PROCESS

Heat Treatment Processes for Steel

Steels can be heat treated to produce a large range of microstructures and properties. Generally, heat treatment uses phase transformation during heating and cooling to change the microstructure in a solid state. In

Furnace at 900 degrees → Graphite → Cooling with the mild steel → Quenching in oil and water

heat treatment, the processing is normally thermal and which modifies only the structure of the steel. In case of thermo-mechanical treatment process of steels, the shape and structure of the steel components also gets modified. In case of thermo-chemical process of steels, the surface chemistry and structure of the steel gets modified. Both the thermo-mechanical and thermo-chemical treatment processes are also important processing approaches for heat treatment of steel and these are being considered in the domain of heat treatment. Heat treatment processes requires close control over all the factors affecting the heating and cooling of the steel. The atmosphere of the heating furnace also affects the condition of the steel being heat-treated.

All the heat-treating processes consist of subjecting the steel to a definite time-temperature cycle. This time-temperature cycle has three components namely: heating, holding at particular temperature range (soaking), and cooling. Individual cases can differ, but certain fundamental objectives are there.The heating rate of a part depends on several factors. These factors are:

(i) heat conductivity of the steel

(ii) the condition of the steel,

(iii) the size and the cross-section of the steel.

The heat conductivity of the steel is an important factor. The steel with high-heat conductivity is heated up at a faster rate than one with a low conductivity. The rate of heating is not particularly important unless the steel is in a highly stressed condition, such as is imparted by severe cold working or prior hardening. In such cases the rate of heating is to be slow. Frequently this is not practicable, since the furnaces used for heating can be at operating temperatures and placing the cold steel in the hot furnace can cause distortion or even cracking. This danger can be minimized by the use of a preheating furnace which is maintained at a temperature below the A1 temperature in the iron-carbon phase diagram. The steel, preheated for a sufficient period, is then transferred to the furnace which is at the operating temperature. This procedure is also advantageous when treating steels having considerable variations in section thickness or which have very low thermal conductivity.

Hardening

Steels can be hardened by the simple means of heating the steel to a temperature higher than the A3 transformation temperature, holding long enough to ensure the achievement of uniform temperature and solution of carbon in the austenite, and then cooling the steel rapidly (quenching). Complete hardening depends on cooling so rapidly that the austenite, which does not decompose on cooling through the A1 temperature and is maintained at relatively low temperatures. When this is accomplished, the austenite start transforming to martensite on cooling below the Ms temperature (around 220 deg C) and is completely transformed to martensite below Mf temperature. Rapid cooling is necessary only to the extent of lowering the temperature of the steel to well below the nose of the S curve . Once this is achieved then slow cooling from then on, either in oil or in air, is beneficial for avoiding distortion and cracking. Special treatments, such as time quenching and mar-tempering, are designed to bring about these conditions. As martensite is quite brittle, steel is rarely used in the as-quenched condition, that is, without tempering. The maximum hardness which can be achieved in completely hardened low-alloy steels and plain carbon structural steels depends primarily on the carbon content.

Tempering

Tempering (sometimes called drawing) is the process of reheating hardened (martensitic) or normalized steels to some temperature below the A1 temperature. The rate of cooling is not important except for some steels which are susceptible to temper brittleness. As the tempering temperature is increased, the martensite of the hardened steel passes through stages of tempered martensite and is gradually changed into a structure consisting of spheroids of cementite in a matrix of ferrite (formerly termed as sorbite). These changes are accompanied by a decreasing hardness and increasing toughness.

The tempering temperature depends upon the desired properties and the purpose for which the steel is to be used. If substantial hardness is essential, then the tempering temperature is to be low. On the other hand, if substantial toughness is needed, then the tempering temperature is to be high. Proper tempering of hardened steel needs a certain amount of time. At any selected tempering temperature, the hardness drops rapidly at first, gradually decreasing more slowly as the time is prolonged. Short tempering periods are normally undesirable and are to be avoided. Good practice needs at least 30 minutes (or preferably, 1 to 2 hours) at tempering temperature for any hardened steel.

The necessity for tempering the steel promptly after hardening cannot be overstressed. If fully hardened steel is allowed to cool to room temperature during hardening there is a danger of the cracking of the steel. Carbon steels and most of the low alloy steels are required to be tempered as soon as they are cool enough to be held comfortably in the bare hands. Steels are not to be tempered before they cool to this temperature because in some steels the Mf temperature is quite low and untransformed austenite can be present. Part of all of this residual austenite transforms to martensite on cooling from the tempering temperature so that the final structure consists of both tempered and untempered martensite. The brittle untempered martensite, together with the internal stresses caused by its formation, can easily cause failure of the heat-treated steel part. When it is possible that such a condition exists, a second tempering treatment (double tempering) is to be given to temper the fresh martensite formed on cooling after the initial tempering treatment.

If structural steels are to be used in the normalized condition, the normalizing operation is frequently followed by heating to a temperature of around 650 deg C to 700 deg C. The purpose of this treatment, which is also designated as tempering, is to relieve internal stresses resulting on cooling from the normalizing temperature and to improve the ductility of the steel.

BATTERY MOUNTING

- Integrated into the chassis to **reduce weight and complexity**
- Chassis was extended to **improve weight distribution** it also helped in reducing the turning angle , pitching tendency and also ensured the battery sat firmly on the front wheels.

DESIGN OF A NEW STEERING SYSTEM

This was necessary as the previous model was not compatible with our new design due to the motor position and the new chassis length. The first step was calculating the required steering torque using the calculations shown. The steering angle was calculated using the ackerman geometry

$$R = \frac{b}{\sin\phi} + \frac{a-c}{2}$$

$$\theta = \cot^{(-1)} \cot\left(\frac{\phi - c}{b}\right) = 11.5$$

$$\phi = \left[\sin^{(-1)}\right]\left[\frac{b}{\left(R + \left(\frac{c-a}{2}\right)\right)}\right] = 10.5$$

Total steering angle $\phi + \theta = 22$

R: Turning radius
Θ: Inner steering angle
Φ: Outer steering angle

Steering ratio $\frac{364}{22} = 16 : 1$

$$\text{Total angle turned by steering wheel} = \frac{Lock\ \text{to}\ lock\ rack\ distance}{2 \times 3.14 \times \text{pinion}\ radius}$$

$$= 1.01 turns \times 360 = 364$$

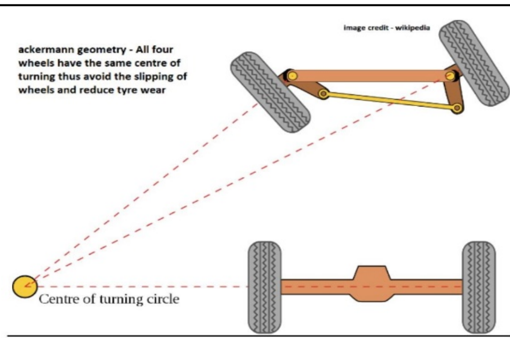


Figure -: 1 Ackerman geometry

FABRICATION OF NEW STEERING SYSTEM

This was achieved by an ingenious use of universal joints meant for box spanners. These were modified to make the double joints that allowed a tilt angle of up to 90 degrees and were far lighter.

we also modified a rack and pinion meant for Toyota car. This helped reduce the steering effort and accommodated the chassis extension.

Designed steering

system

Steering column and steering rack installed

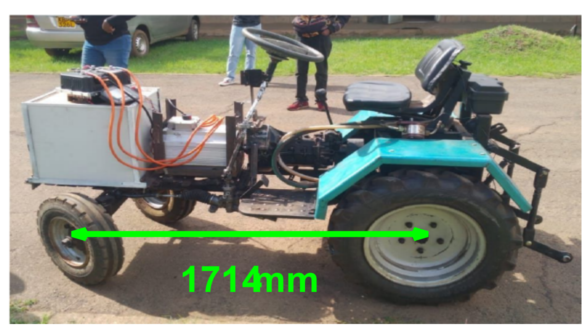
on the tractor

Checking the steering

ADJUSTMENTS ON STABILITY

(i) **Wheelbase** was increased by 200mm

(ii) **Yawing** and **pitching** of the tractor was **reduced**



CHALLENGES

- Inexperience in the field of advanced testing and simulation
- Lack of technical knowledge in some research areas

REMAINING ISSUES

In the next prototype, there are a few changes to be made to make it ready for production. These are such as;

- Incorporation of a **suspension** to improve ride quality
- Implementation of **traction control** to improve stability
- Upgrading braking from **2 wheel drum brake** to **hybrid disc** and **drum brake**.
- Incorporation of **power steering**
- Incorporation of **all wheel drive** with torque vectoring