Design , Analysis and Fabrication of a Crawler Robot

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Abstract:*In the context of advanced technology scientists and engineers use complex mechanics and control engineering to make power machines which can do human like work on large scalein mass production or intricate work like neural surgeries in medicine. This necessity has fueled the science of robotics and hence continuous research is being done in this field and recently incorporating other areas like biotechnology, genetics, nanotechnology, aerodynamics etc. to improve human lives in future. Robots find their application everywhere varying from space, military, medicine, domestic to manufacturing industries. The Crawler robot is a very popular project in these fields. Thus a lot of work is being done on this robot. The scope of this paper is to design and fabricate a robotic Crawler (a basic model of what can be a complicated, versatile bot) operated by RF Technology and hopefully give some new ideas for the construction of future Crawlers working in hazardous areas, military surveillanceand aerospace, marine, mining etc.. The present paper entitled "Design and Fabrication of a Crawler Robot" is the work done for the design, analysis and fabrication of small working robot. Modeling is done on SOLIDWORKS software and analysis using ANSYS.*

Keywords*: Design, Stress Analysis, Robot, Control Systems, Embedded technology, RF Technology*

1. INTRODUCTION

The history of robots has been debated since the ancient worlds. The modern design and technology matured with the boom of the Industrial Revolution, which incorporated the science of complex mechanics and electricity. Early machines were built with small compact motors and gradually resulted in human like the one androids with the ability for near human intelligence; senses and feelings.Hence researches are done on various levels of technological sophistication, ranging from a simple material-handling device to a humanoid. Early robots were first used as fixed machines in factories to manufactureproducts allowing production without human assistance. Robots making use of AI (Artificial Intelligence) and digitally controlled industrial robots and have been developed since the 1960s.Industrial robots have developed by two technologies: *numerical control* for machine tools, and *remote manipulation.* The first *master-slave manipulator* system was developed by 1948. Leonardo da Vinci's drawings of machines that fly like birds sparked inventors to create biological inspired robots. It was not until the middle of the 19th century that technology started developing and truly successful attempts to make walking or crawling robots proliferated only in the last few decades of the 20th century (e.g., Raibert, 1986, 1990).In recent years a number of robots have been developed that draw their inspiration from running animals including *Sprawlita*, *Scorpion*, *Whegs*, *Mini-Whegs*, *iSprawl*, *Cheetah*and *RHex.*

Crawler is also inspired from animal designs and it possesses special problems for robotics; in general it is possible to outline that:

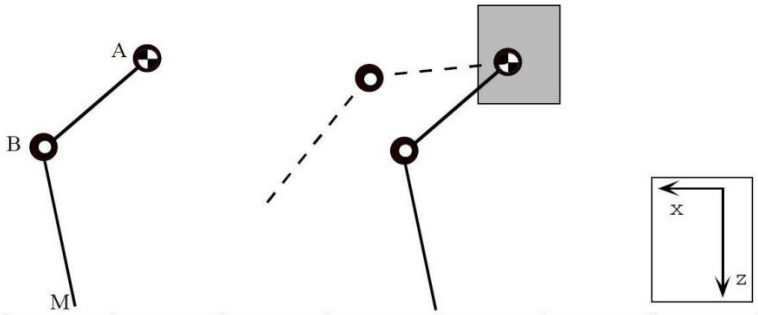
- Walking mechanisms suited to traverse extreme terrain.
- Sensors: perception, motion control etc.
- Robotic arms for handlingobjects.
- On-board power source and actuationfacilities.

This prototype uses theory of machines in transferring the motor revolutions to reciprocating motions via crank and dynamic linkages. Every device will be arranged on the Crawler to keep its center of mass as low as possible, in order to have an easier control of the dynamic equilibrium.To complete the design of the crawler it is important to first create model prototypes around the basic idea. The theoretical design calculations are done and appropriate dimensions are chosen. Changes are made based on the required mechanical working modeland the material is chosen. The modeling is then done on modeling software and the load analysis is done on analysis software. Then the model is optimized and the final design is approved. Next step is the fabrication and the incorporation of control structure elements.

2. DESIGN ANALYSIS

Kinematic Links

In this work selection of legged locomotion was done because of its characteristics like superior ability to traverse in rough-terrain, theoretical efficiency and ability to keep sensors and sampling equipment steady and stable. The functional schemes of the legs, presented in the following are sketched with reference to the following graphical symbols**:**



mobility	workspace	load capability	upright posture	x,z	suspensions	retractability
2 DOF	wide	medium	yes	independent	good, adaptable	very good

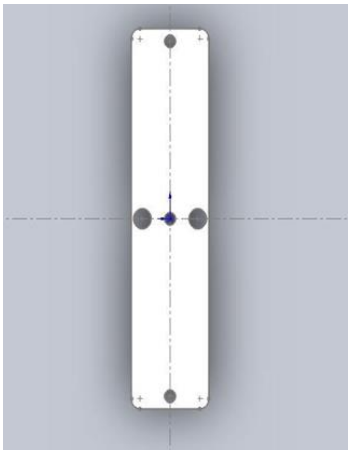


Figure1. 2D View of the leg shapes using Solid Works modeling

As shown above, the double pendulum leg is chosen for robot locomotion. This architecture offers very wide workspace. The load capability is quite good, but the weight of the research tools is not too high. (Figure 1 shows immediate view of the leg shapes using SolidWorks modeling).The leg dimensions have to satisfy different conflicting specifications; the legs have to be:

1. Long enough to overcome the considered obstacles maintaining the right horizontal attitude of thebody;
2. Rigid to hold up the bodyload;
3. Elastic to act as a good suspension mechanism.
4. The first considerations define the link length; the last two suggest the shapes and the thickness of the links.

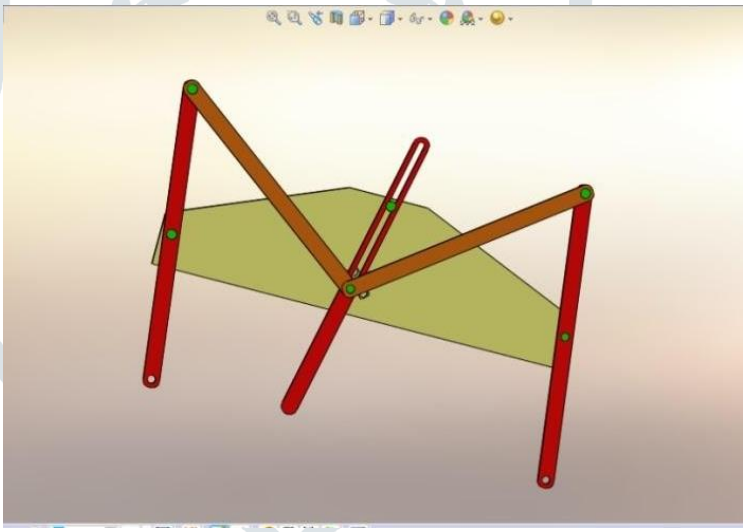


Figure 2 The basic structure chosen for this prototype

The Prototype was modeled on Solid Works 2010 ®. It was designed as a four-legged crawler with two legs in front and two at the rear and an additional third leg in the center. The servo motor actuated the third leg which worked on the principle of slider crank mechanism as shown in figure 2.The third leg ensured proper balancing and stability of the crawler. Two servomotors were employed on either side of the crawler to ease maneuverability without the use of additional mechanisms. The basic structure chosen for this prototype as shown in *figure 2*

Each leg on the extremities is a plate fixed on the mounting plate by means of a nut and allowing pivoting action. Theselegs are connected to the central leg by means of a connecting rod. Each central leg is the familiar slider crank where crank is extended to form the leg shown in figure. The mechanism of the central leg is basically a series of slider crank mechanisms, whereas the end legs are actuated by the mechanism of crank and connecting rods. Hence due to the connections of the linkages to one crank which in this case isa servo horn enables the fluid transfer of motion to all three legs.It was powered by an A/C motor driving a shaft connected to the two servo horns and actuation from the motor was transferred by spur gear setup.

Leg Dynamic Simulation

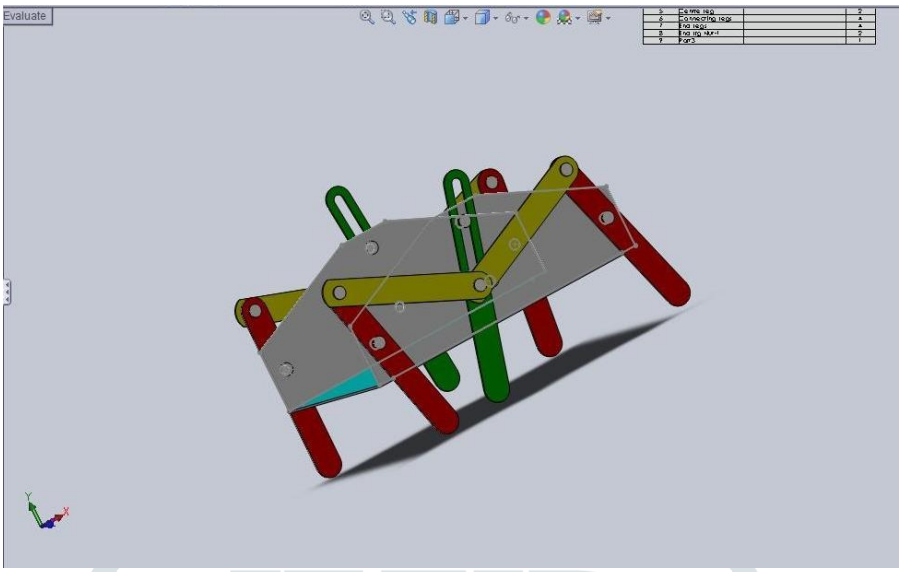
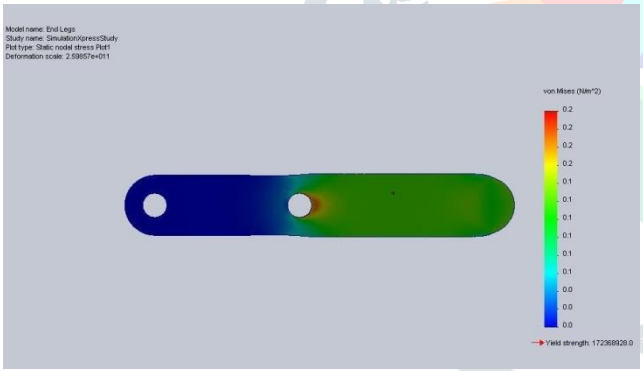


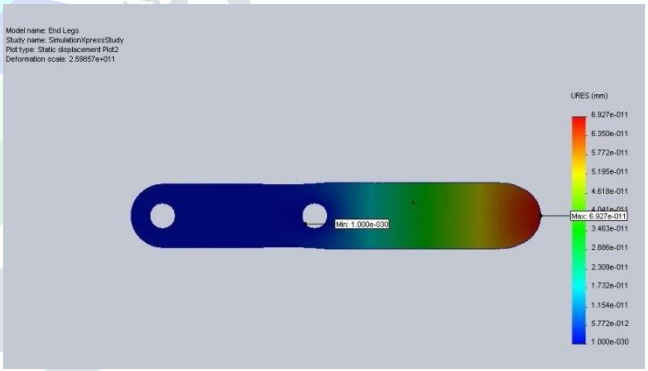
Figure 3 Solid Works Simulated Model

Based on the design adopted it was decided to use Aluminum for the base and mounting plate while Stainless Steels for the legs for analysis.

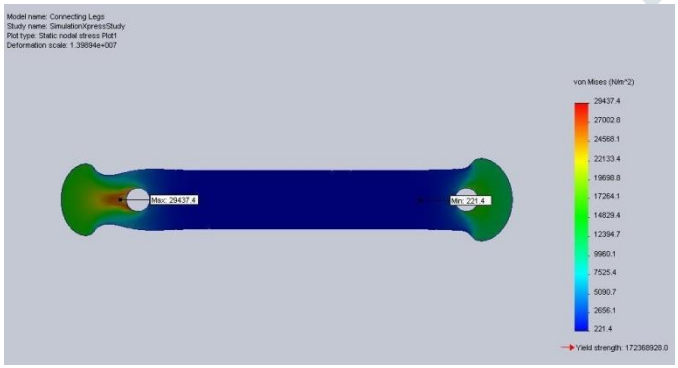
3. STRESS AND LOAD ANALYSIS

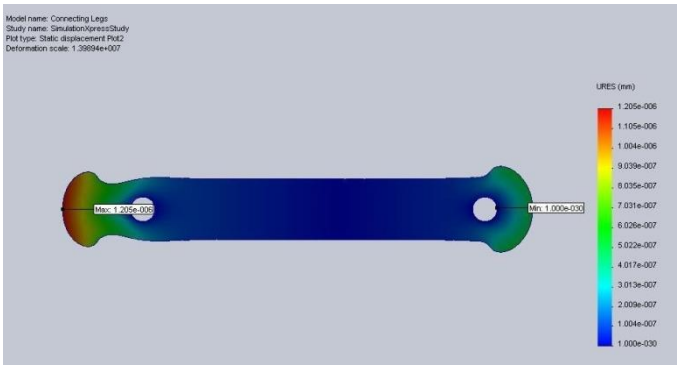
ENDLEGS:



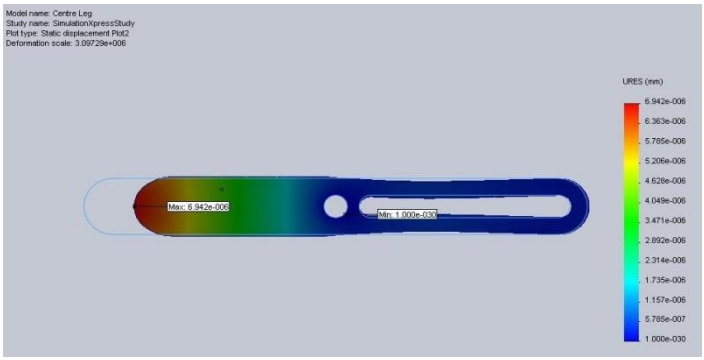


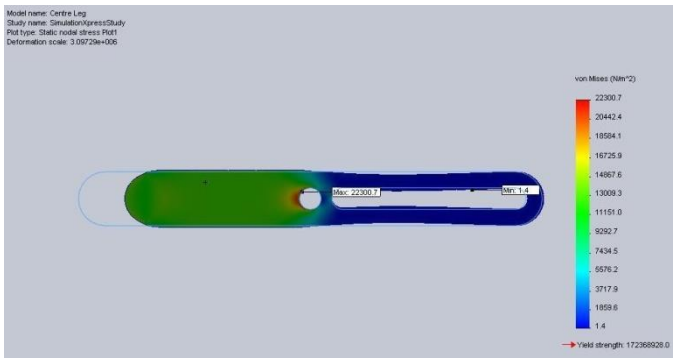
CONNECTING LEGS:





CENTRE LINK:





4. MANUFACTURE AND ASSEMBLY OF THE CRAWLER

A *mockup* was first made in Styrofoam sheets (polystyrene). Then mockup was created using plywood actuated by an A/C motor (Figure)

Figure 4 A Prototype Model

The final model of the Crawler was then fabricated in metal. For the base and mounting plate *Aluminum Chequered Plates* and for the legs *Ferritic Stainless Steel* (AISI 400s series) was used.

5. CONTROL SYSTEM

RF Based Robots use *Embedded Systems* and *RF technology* to operate. The control system consists of a switch control module, fire sensor, metal detector circuit, RF transmitter and receiver section, microcontroller and the robotic arrangement.

COMPONENTS OF CONTROL SYSTEM

REMOTE

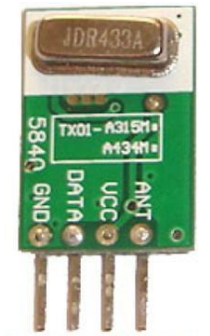
The remote contains five switches (forward, backward, left, right and stop), encoder and transmitter.

RF TRANSMITTERSTT-433 MHz.

The STT-433 is where low cost, large volume and longer range (operating frequency 433.92 MHz). The transmitter operates from a1.5-12V supply, making it ideal for battery-powered applications. The transmitter employs a SAW-stabilized oscillator, ensuring accurate frequency control for best range performance.

RF RECEIVER STR-433 MHz:

The data is received by the RF receiver from the antenna pin and this data is available on the data pins.



STT-433 MHz TRANSMITTER

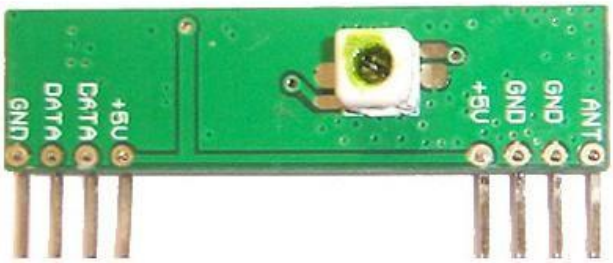


Figure : 5. Micro Controller and Transmitter

METAL DETECTOR

The metal detector used is a 3-pin device. The output of the metal detector is given directly to the microcontroller.

FIRE SENSOR

The prime function of a fire detector is to detect one or more changes in the protected environment indicative of the development of a fire condition. The fire sensor used is a 3-pin device

WIRELESS CAMERA

Integration of video surveillance in the Crawler enables to remotely monitor the activities and guide the Crawlerin inaccessible areas by human. Crawler uses the software Wwigo® which enables camera imagetransmission via Bluetooth® interface thus streaming the video from camera to PC.

CIRCUIT DIAGRAMS OF THE CONTROL SYSTEMS:

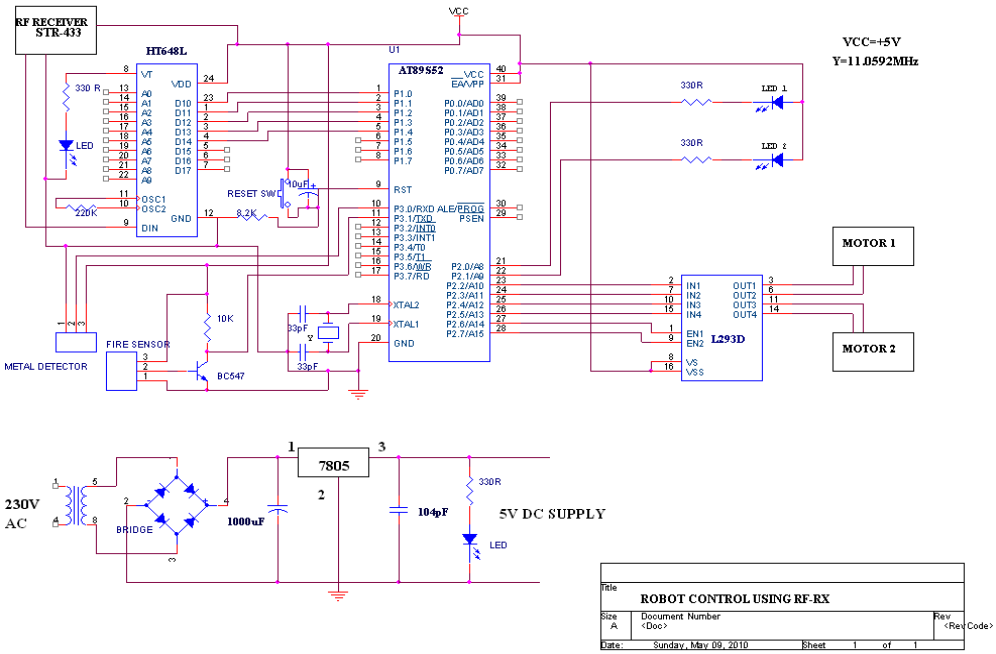


Figure 6: Circuit Diagram

WORKING OF THE CONTROLSYSTEM:

1. To control the direction of the Robot, predefined keys give commands from the transmitter section. The transmitter transmits this data into air by converting digital signals into analog.
2. The receiver gets the data and decodes it to digital form and sends to the microcontroller.
3. The microcontroller checks for the data received from the transmitter section and monitors the output of fire sensor and metal detector circuit and changes the direction of the ROBOT according to the input received from the transmitter side and glows the corresponding LED when any of the sensors trigger.
4. Thus, the Robot will be moved in that particular direction with the help of L293D driver.

APPLICATIONS

- Navy: attaching sonar device to record landscape in dark places.
- Disaster Situations: search and rescue missions in inaccessible areas
- Military: bomb diffusing squad, remote surveillance, ground troops using infra-redscanners.
- Un-manned Exploration: space and underwater to collect pictures and material samples.

6. RESULTS

- After the Analysis of the Craweler the following results are obtained

Part of the Crawler	Material	Mass(Kg)	Volume(m^3)	Maximum Stress (N/m^2)
End Legs	AISI 316 Stainless Steel Sheet (SS)	0.0673407kg	8.41759 x $10^{-6}m^3$	0.222797 N/m^2
Connecting Legs	AISI 316 Stainless Steel Sheet (SS)	0.0630875kg	7.88594 x $10^{-6}m^3$	29437.4 N/m^2
Centre Legs	AISI 316 Stainless Steel Sheet (SS)	0.0685407Kg	: 8.56759x $10^{-6}m^3$	22300.7 N/m^2

7. CONCLUSIONS

1. The Crawler Robot was designed with double pendulum kinematic legs.
2. The Model had two legs in the front, two at rear and two in the middle.
3. The Middle leg was given power using servo motor and the front and rear legs were connected using connecting legs.
4. The Materials selected were *Aluminum Chequered Plates* for the base and mounting plate and *Ferritic Stainless Steel* (AISI 400s series) for the legs.
5. The robots used *Embedded Systems* and *RF technology* to operate.
6. The control system consisted of a switch control module, fire sensor, metal detector circuit, RF transmitter and receiver section, microcontroller and the robotic arrangement.
7. The model is a basic version of what can be complicated versatile bot used in future applications.

8. REFERENCES

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