Design of battery pack & controller for combined auto driven mini-harvester

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Abstract: The mechanized farming can promisingly increase the profitability and prevent the dependency of farmers on foreign labours. The design and implementation of Battery pack and controller for specially designed combined auto-driven mini harvester is presented in this paper. The mechanical load estimation and its mapping with electrical drives are formulated. The interfacing of electrical drives with remote operation is achieved by Electronic Arduino system. The relay control system is designed with individual drive system. The sketches are mapped with the functionality of drives. The drive selection is a dependent function of mechanical load requirement. The mechanical load estimation is done with actual mechanical failure consideration and design approach. The pin-out connections for all the ports are done on the basis of logical sketch command. The open source Arduino software is used to run the sketches. The sketch written for all the drives is compiled and demo prototype machine is tested for functioning. The run trail is successful and can conclude that the Arduino mega gives the sound interface with 8 channel relay. The computation and measurement results of power requirements for the controller and drive are within the limiting conditions.

Keywords: Arduino Sketch development, Battery-pack design, Electro-mechanical load mapping, Relay interface, Remote operation

1. Introduction
The explosion of population causes upmost requirement of food & agricultural goods all over the world. The shrinking fertile land size is making farmers incapable for adoption of bigger farm machineries. Though the advancement and development in the field of agriculture taking place promisingly still the adoption and implementation for the small countries like India, Indonesia, Brazil is rare or mostly unseen [1]. The combined harvester available is limited for large farm fields and rich farmers. Though attempts have been made to address the issue of small farmers still the problem remain unsolved. [1] The post harvesting operation is most labour intensive work [2]. The post harvesting has to be performed in the hot dry whether to trace the maximum yield. The favourable condition leads to the operating temp about 40°C [3]. The manual operation at such an operating temperature leads to severe health issue or may cause death due to heat stroke. The detailed literature review and market survey gives the traces for unavailability of combined mini harvester. The available combined harvester with their capacity and capability & constraints are deeply studied and presented by present
researcher in open source journal. The findings lead to the conclusion that no combined mini harvester is readily available to fulfill the requirement. [4]

To take up the issue an attempt is made to design the combined auto driven harvester. The combined auto-driven harvester is very novel machine specially designed for the small farmers. The machine performs the combined operation of cutting, threshing, grain separation, husk trapper and husk compacting at the same time in the farm field itself. The mechanical design and mechanism simulation trial is over and work is presented in conference journal by present researcher [5]

The said machine is auto-driven with all the drives run through remote controlled Bluetooth interface Arduino controller. The electrical load requirements for the different mechanisms are mapped with the mechanical load. The electrical drives serve the mechanical power requirements. The reference of auto-driven robot cars and remote controlled mechanism is taken to formulate and initiate the design [6]. The concept of using Arduino for developing microcontroller based projects has been extended in this research.

For technical development of the model the design constrains are given in the form of geometrical configuration. Taking into consideration about its compact design the harvesting blade span is limited for covering three crops in single trail. The mechanical and thereby electrical load requirements are thus formulated for the strength and some physical parameters for the said configuration.

1.1. Estimation of load requirement
The configuration of combined harvester with its major components is shown in the figure below. The machine is designed with a view to develop the combined mini harvester for small farmers. The load requirement is considered on the basis of design calculations formulated for the mini harvester. The reference design calculation provides a basis for load estimation in present work [5]. The given mechanical load requirements are fulfilled through the electrical drives. The load estimation for individual drives is formulated with the concept of system design. In system design the whole machine is subdivided in small machine subassembly and mechanisms. Adopting the same concept for electric load calculation the major mechanical load requirements are identified as

![Combined Harvester Diagram](image)

Figure 1. Combined Harvester

1. Cutter drive
2. Thresher drive
3. Electrostatic husk trapper
4. Drive for Dry compactor
5. The Drive mechanism
1.2. Load calculation for thresher drive
The thresher mechanism is a drum assembly driven by electric motor to impart the contact friction and impact shear on the crop bulk [7]. The electric load requirement is formulated with the reference of mechanical load calculation. The mechanical & electrical load requirement are formulated as under

\[
\text{Total load} = \text{Static load} + \text{Dynamic load} \tag{1}
\]

\[
\text{Static load} = \text{Self weight} + \text{Inertia force} \tag{2}
\]

\[
\text{Self weight} = m \times g \tag{3}
\]

\[
\text{Mass} (m) = \text{Density} (\rho) \times \text{Volume} (V) \tag{4}
\]

With the reference of design calculation Thresher drum is made up of cast steel. So, \( \rho \) is 7800 kg/m\(^3\). The mass of Thresher assembly is 49.68 kg. With consideration of maximum 10 % inertia force on the self load the static load is 303.88 N.

The dynamic force for performing the threshing is 130.9 N. Total force requirement is 434.9 N. Thresher drum speed is 748 rpm. With the torque radius of 175 mm gives the total power requirement of 7.5 Kw at 750 rpm standard electric motor. With speed reduction gearbox having velocity ratio of 6 the desired motor required is 1.25 Kw having rpm 6000.

1.3. Electrostatic husk trapper mechanism
With the reference of design formulation & calculation for static cling the power requirement is given as

\[
P = \text{Current} (I) \times \text{Volt} (V) \tag{5}
\]

For the current of 16.485 amps and 48 V gives the power requirement as 810 W.
1.4. Drive for dry compactor
The test trail results for making the husk bricks gives the dead load requirement of 8 KN force acting on brick area of 400 mm\(^2\). The given load requirement leads to the selection of hydraulic power pack of 3.2 bar capacity. The power requirement for power pack motor is 750 W.

![Figure 4. Compactor Power Pack](image)

1.5. Drive for cutter
The cutter drive is a blade assembly impart dynamic shear on the crop bulk. The concept mechanism diagram shown in Figure 05. The dynamic shear is applied by drum mechanism driven by an electric motor coupled through gearbox.

With the reference of geometrical configuration the weight of drum is 54.55 kg. With the consideration of 10% inertia load gives the static load on cutter drum is 633 N. The dynamic force for cutting is calculated with the reference of crop shear strength and core stem area. Considering the strongest crop stem for design formulation i.e. soybean with shear strength of 2.67Mpa [8] and maximum core area of 20 mm gives the cutting force requirement of 2515.5 N for cutting three corps in a row.

Total force acting on drum assembly is 3148 N. To provide the cutting thrust the torque applied on 450 mm cutter drum is 633.44 Nm. For the designed peripheral speed of 6 m/sec with 450 mm drum the speed of drum is 254.77 rpm.

The power requirement for cutter assembly is 16.20Kw at 254 rpm. The speed reduction gearbox leads to the power requirement. Using gearbox with velocity ratio of 10 reduces the power requirement to 1 Kw double speeds motor.

![Figure 5. Cutter Drive](image)

1.6. Drive mechanism
With 4 x 4 transmission system and total dead load of 300 kg leads to the static load on machine as 2.943 KN. With the reference of tyre rim assembly selected for the load and application leads to the torque requirement of 441Nm. The propelling speed of machine is 1.4 f/sec gives the power requirement of motor with 2 Kw capacity and 6 speed reduction gearbox. The all wheel drive approach gives the power requirement for each drive motor as 500 Watt.
2. Selection of battery pack
The analysis of mechanical failure and estimation of actual electrical load gives an account of true electrical load requirement. The true design power load requirement for given machine considering the different drives leads to the total power load requirement as 7.5 Kw battery pack system. With the consideration of general power factor of 0.86 [9] for single Phase motor the actual power requirement is 8.5 Kw. The line diagram for single main power distribution is as shown below.

3. Simulation of drives
To inline the total drives in machine with standalone power source leads to the design of monotonous controlling system. Also, the machine operates in the dry hot weather condition with minimum operating temperature of above 40 degree [3]. The stated constraint leads to the requirement of remote operation. To fulfil the demand the system is integrated with the remote controlled drives through Arduino interface. The Arduino controlled power management system operates the function of high voltage drives via low voltage electric module i.e. relays [10]. The serial data feed into the Arduino through the program designed for individual drive. The microprocessors fetch the command and perform the logical operation. The logical pin-out connection fetches the data input for individual port and processes for operating the relays [10].
4. DESIGN OF CONTROLLER

The logical relationship between drives and relay shown in fig.08 gives the address note of high data transmission between the ports. The 8 relay operation for the controlling of machine with minimum lag demands strong data processor. The high end processor available with Arduino Mega serves the purpose with an added benefit of 18 serial (TX) transmission ports [1].

The operation of individual drives is analysed and algorithm is plotted for all the drives. The sketch is developed for all the drives taking into consideration of functionality and logical screening of all the ports. The digital data transmission is addressed in the sketch for minimum lag [I]. The logical pin-out connection for all the ports is as shown.

Figure 8. Drives Logical Configuration

Figure 9. Arduino & Relay Interface
5. Selection of relay channel kit
With the reference configuration diagram and electrical load requirement leads to the motor requirement as follows

- Drive motor – 500 W 3000 rpm
- Thresher motor – 1.25 KW at 6000 rpm
- Hydraulic power pack motor – 750 W at 1000 rpm.
- Cutter motor – 1 KW at 6000 rpm.
- Electrostatic husk trapper – 810 W

The high power management leads to the use of relay circuit. The readily available 8 channel relay circuit serves the purpose.

![Figure 10. Relay & Drives Interface](image)

The 8 channel relay kit provides an interface for connection of high power equipment with low power controlling equipment [II]. In present work all the ports of 8 channels relay module is used thus provided with 8 pin-out connection including the ground and VCC pin-out connection [12]. The logical connection pin-out junction is stated as below

- Logic GND: Connected to GND on Arduino.
- Input 1 (IN 1): Connected to digital pin D1 on Arduino.
- Input 2 (IN 2): Connected to digital pin D2 on Arduino.
- Input 3 (IN 3): Connected to digital pin D3 on Arduino.
- Input 1 (IN 4): Connected to digital pin D4 on Arduino.
- Input 2 (IN 5): Connected to digital pin D5 on Arduino.
- Input 3 (IN 6): Connected to digital pin D6 on Arduino.
- Input 2 (IN 7): Connected to digital pin D7 on Arduino.
- Input 3 (IN 8): Connected to digital pin D8 on Arduino.

```c
#define RELAY1 7 //Defining the pin 7 of the Arduino for the 8 relay module
#define RELAY2 6 //Defining the pin 6 of the Arduino for the 8 relay module
#define RELAY3 5 //Defining the pin 5 of the Arduino for the 8 relay module
#define RELAY4 4 //Defining the pin 4 of the Arduino for the 8 relay module

void setup()
{
pinMode(RELAY1, OUTPUT); //Defining the pin 1 of the Arduino as output
pinMode(RELAY2, OUTPUT); //Defining the pin 2 of the Arduino as output
pinMode(RELAY3, OUTPUT); //Defining the pin 3 of the Arduino as output
pinMode(RELAY4, OUTPUT); //Defining the pin 4 of the Arduino as output
}
```

6. Arduino coding
The combined harvester consists of 8 machine drive components [5]. The 4 machine drive components listed as R2 , R3 , R6 , R7 used to drive the machine (machine propelling). Whereas the remaining machine drive listed as R1 , R4 , R5 , R8 used to run the cutter, power pack and husk trapper & the thresher ref. Fig 1.

The machine drive motors needs to be programmed separately with the concept of robot cars.
The logical approach is as below

- Drive motors - R2, R3, R6, R7.
- R2, R3 - Left Drive motors
- R6, R7 - Right Drive motors
- Forward motion - R2, R3, R6, R7 High
- Left turn - R6, R7 High
- Right turn - R2, R3 High.
- Reverse Motion - H Bridge activate.

```
char t;
void setup()
{
  pinMode(2, OUTPUT); //left motors forward
  pinMode(3, OUTPUT); //left motors reverse
  pinMode(6, OUTPUT); //right motors forward
  pinMode(7, OUTPUT); //right motors reverse
  pinMode(9, OUTPUT); //Hbridge
  Serial.begin(9600);
}
```

The machine drives R1, R4, R5, and R8 are constant drive motor runs on the constant speed input, pinned connection as D1, D4, D5, D8. The relay acts as a switch and controls the power for motor. The Arduino digital pin used to turn the relay on and off and is given the name ‘motorpin’ in the sketch. In order to maintain the constant speed of motor a potentiometer is connected in-line with the drive motor to ensure the constant torque on mechanisms.

```
int motorPin = 1,4,5,8; //Relay assign
void setup()
{
  pinMode(motorPin, OUTPUT);
  Serial.begin(9600); //Set constant moor speed
}
```

7. Bluetooth interface

The Bluetooth module HC 05 is used to provide the wireless interface between the remote mobile control and Arduino setup. HC 05 receive the serial communication command through the android app is designed for sending serial data to the Bluetooth module. The data received at Bluetooth module send to Arduino through the TX pin of Bluetooth module (RX pin of Arduino). The Code received at Arduino check the received data and processes the command.

```
data = Serial.read(); //Read the incoming data and store it into variable data
Serial.print(data); //Print Value inside data in Serial monitor
Serial.print("\n"); //New line
if(data == '1') // Checks whether value of data is equal to 1
digitalWrite(13, HIGH); //If value is 1 then LED turns ON
else if(data == '0') // Checks whether value of data is equal to 0
```

![Figure 11. Bluetooth Interface](image)
8. Results & discussion

The 8 channel relay kit is wired as per the drive design and the logical pin-out connection is done. The Arduino sketch is compiled and run through the interfacing Bluetooth module. The true operating parameters in the form of required current and voltage required is computed. For each drive the operating parameters are calculated with the power factor of 0.86 and efficiency of drive as 90 %. The power requirement on drives and controller relay module are as under.

Table 1. Relay & Drive Control parameters

| Relay port | Drive name               | Electrical load (KW) | Drive parameter | Controller parameter |
|------------|--------------------------|----------------------|-----------------|----------------------|
| 1          | Thresher Drive           | 1.25                 | 41.35           | 37                   | 6.46                 | 4                       |
| 2          | Left Drive Motor 1       | 0.5                  | 55.64           | 11                   | 3.22                 | 2                       |
| 3          | Left Drive Motor 2       | 0.5                  | 55.64           | 11                   | 3.22                 | 2                       |
| 4          | Power Pack               | 0.75                 | 54              | 17                   | 4.84                 | 4                       |
| 5          | Husk Trapper             | 810 W                | 20.65           | 48                   | 5.23                 | 3                       |
| 6          | Right Drive Motor 3      | 0.5                  | 47.08           | 13                   | 3.48                 | 2                       |
| 7          | Right Drive Motor 4      | 0.5                  | 47.08           | 13                   | 3.48                 | 2                       |
| 8          | Cutter Drive             | 1                    | 58.29           | 21                   | 6.45                 | 4                       |

The power requirement for each drive is calculated and the desired controller requirement is mapped. The calculation and measurement result shows that, the power requirements for relays are under the limiting conditions of relays.

9. Conclusion

The method of mechanical design load estimation is stated in this work. The mechanical and electrical load mapping is done and stated the drive system requirement. The power load calculation and selection of power-pack is done with suitable power factor for actual drive system. The formulation of method for sketch development is stated and sketch is run on Arduino free source software. The sketch developed for drive interface is run and trail is successful. Arduino mega provides successful interface with 8 channel relay board. The lag time for drive control is almost negligible.

Acknowledgments

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References

[1] Department of agriculture and Farmers Welfare 2019 List of Combine Harvesters Tested at the Farm Machinery Training & Testing Institutes Mechanization & Technology Division, Department of Agriculture & Cooperation, New Delhi June 2019

[2] Hegazy, Rashad. 2013. Post-harvest Situation and Losses in India. Technical Report · June 2013 10.6084/m9.figshare.3206851.v1.

[3] Omafra staff. 2014 Soybeans: Harvest and Storage. Agronomy Library Harvest Timing http://www.omafra.gov.on.ca/ Additional Sources: August 2014
[4] Rahul S. Warghane et.al. 2018, Review on Design and Optimization of Thresher In Crop Cutting Machine International Journal of Mechanical Engineering and Technology (IJMET) Volume 8, Issue 11, November 2017, pp. 1020–1028.

[5] Rahul Warghane ,Rajkumar E 2018 ‘Design and Synthesis of Crop Cutting Machine’ International Journal of Advanced and Innovation Research ,Volume 03 Issue 06 Pg 92-94 ISSN NO :2278-7844

[6] Bagloee, S.A., Tavana, M., Asadi, M. 2016 Autonomous vehicles: challenges, opportunities, and future implications for transportation policies. J. Mod. Transport. 24, 284–303 (2016). https://doi.org/10.1007/s40534-016-0117-3

[7] Brandini, Adhemar, 1969 . Corn kernel forces during impact shelling , Retrospective Theses and Dissertations. 14482. https://lib.dr.iastate.edu/rtd/14482

[8] Piotr kuźniar 2016, Physical and chemical properties of soybean seeds determine their susceptibility to mechanical damage. Zemdirbyste-Agriculture ISSN 1392-3196 Vol. 103, No. 2

[9] Khan, Muhammad. 201). Speed Control and Power Factor Improvement of Single Phase AC Motor. Universal Journal of Electrical and Electronic Engineering. 2. 328-336. 10.13189/ujeee.2014.020804.

[10] Oussama ben belgith, lasaad sbita, 2014 Remote GSM module monitoring and Photovoltaic System control , First International Conference on Green Energy (ICGE) 2014

Digital handbook:
I. Digital Acoustics Corporation Text Speak Design Group, Westport, CT 06880 U.S.A.
II. Handson Technology “8 Channel 5V Optical Isolated Relay Module” http://www.handsontec.com/