11th International DAAAM Baltic Conference
"INDUSTRIAL ENGINEERING
20-22 April 2016, Tallinn, Estonia

ROLLING TYRE COUNTING SYSTEM

SINANI, U.; SAJEDI SABEGH, N.; Hiiemaa, M. & Tamre, M.

Abstract:
Rolling Tyre counting system is a PLC[1] based controller to count the number of tyres, detect direction, measure velocity and display results on the monitor. The measured data obtained can be accessed later. Since the developed system is portable, it does not require an additional conveyor belt. The developed system can be installed everywhere. The proposed system is working indoor and outdoor with different lighting conditions and the results presented in this work are quite promising.

Keywords: Tyre counting, Tyre Detection, Tyre velocity measurement, time log, logistics.

1. INTRODUCTION

Existing tyre counting solutions are mostly based on detecting and counting on a conveyor belt in a factory or site, which is fixed in place. Such systems are applied for counting in normal condition and require special design of system. Moreover, as they require installation space, are relatively big, and can be used for indoor only applications. Hence, tyre detection, counting, logging, and reliability [1] are important for the developed system. The mechanical design for the model was done according to the real dimensions of tyres for the height and for width; we considered real dimensions of container where this system is conceptualized. In addition, some dexterity is added to the frame and other mechanical parts, which makes the parts easily attachable and detachable creating more flexibility and rigidity. In sections below, you will get to know also about sensory type that was used for the system. Where research work was done by choosing lasers and LDR[2]s, instead of machine vision.

2. Concept

The concept used consists of 5 cells and 5 LDRs placed in a line of sight from each thus creating a barrier like scene to cover the area where tyres will pass through, as it is shown in figure 1. Therefore, laser lines will be blocked by rolling tyres and LDRs, on the other side of the frame, will sense the absence of laser light coming from the opposite direction. From tests we conducted of this model, we compiled a specific logic algorithm that was able to measure different scene situation. Where in section 4 we discuss the algorithm implemented on PLC, section 5 set up conditions and section 6 we analyse the efficiency per each block.

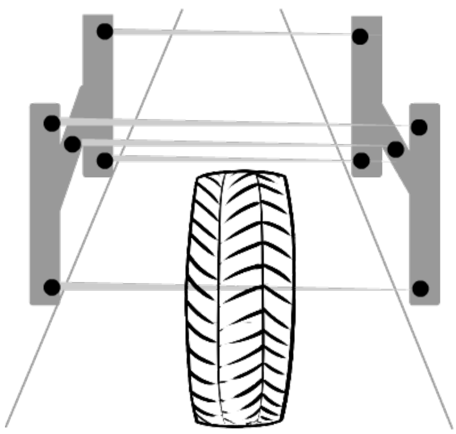

Fig. 1. Tyre passing through the frame

[1] Programmable Logic Controller

[2] Light Dependent Resistor

3. CELL ALIGNMENT

Positions of transmitter and receiver cells are chosen according to tyre size, as to block the light when a tyre passes through them. Moreover, the middle cell is to check if the passing object is a tyre. That is done by implementing an algorithm according to cell numbers and positions on the frame. Written in PLC logic using Functional Block Diagram.

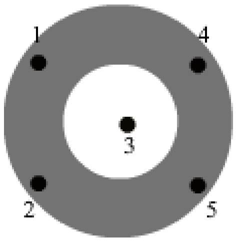

Fig. 2. Alignment of cells

For our model development, we considered a 14” tyre size, according to its sidewall size and diameter. For illustration, cell arrangements and dimensions are 18 cm from the centre to tread and 36cm in height as in figure 3.

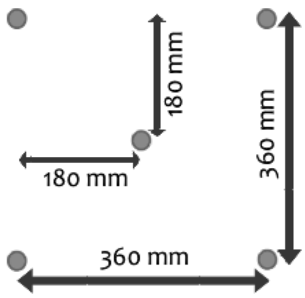

Fig. 3. Alignment of cells for a 14” tyre size

4. PLC

PLC model we used is Siemens LOGO! 0BA8 and control algorithm is written in FBD[3] using “Siemens LOGO! Soft Comfort”. Each block is done by combining different logic gates according to Boolean logic and SIEMENS LOGO provides the interface! Output results when necessary can be read in visual form as tyres are passing through the scene. PLC logic used can well detect tyres between different shapes passing through the scene and counting tyres only and is strong enough not to count wrongly in case of being actuated by random senses. Moreover, the system could well detect rolling direction and measure the time tyre is rolling through the system. Measured timing includes total amount of time needed for the tyre to pass the scene and the time needed for tyre to pass half the scene. Therefore, we could easily compare elapsed time of rolling tyre for each half of the scene and detect abnormalities in tyre movement. By having recorded time, we could also measure rolling tyre speed. In addition, we were logging number of tyres rolling in two directions.

We designed a simple GUI to display all the logged data on PLC screen as it could be seen in figure 4, there are two displays that operator can switch between them by pressing a pre-defined PLC button. In addition, a log file stored on the PLC is accessible to have an overview of all these logged details.

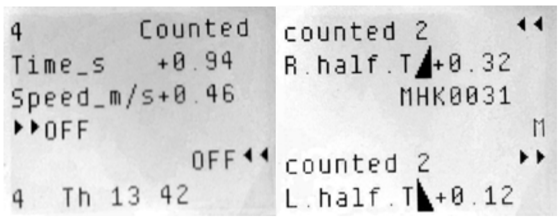

Fig. 4. PLC screen, display one on the left, display two on the right

5. SYSTEM SETUP SCHEME

For the set up two main environment conditions were tested, first, we tested the sensory block with maximum light intensity referred to normal lit environment and for the second test, we took normal light condition followed by a third in complete darkness. After we got measured the sensory block performance. Where in the case of high lit environments the degree

[3] Function Block Diagram

of error was high. LEDs as transmitters could not communicate reliably with lasers, receivers [2]. This test was followed by other block tests such as PLC logic test, simulating the case of different shape objects passing into the scene. And tested electric and electronic block using different cable length with different signal speeds (rolling the tyres through scene very fast).
Therefore, our system is setup containing three main blocks starting with the power block, signal block and logic block. Where when we tested individually each one of them gave acceptable results for the reliability and stability test.

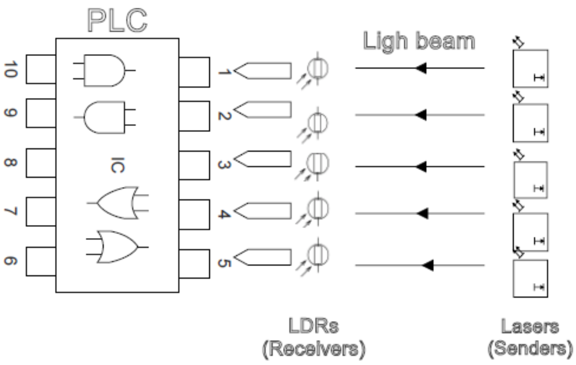

Fig. 5. Sensory block

In figure 5, is presented logic and sensory block composed of transmitters and receivers created by a pair of laser [4] and light dependent resistors. Some technical details pertaining this block are as follow: LDRs manufacturer Silonex NSL-19M51 and laser modules with 650nm light beam and 5mW power [3] consumption operating voltage 5V DC. The block is designed to work on a DC current allowing low power fluctuations provided by the voltage regulator. Also, they are designed not to be affected by different noise levels from the power supply and external EM field, which for different set up conditions can have different impact levels. Five pairs of LDRs and lasers are used to build-up a cell like matrix that is to create more solid and power fixed sensory block. Where we then take, the signal inputs from this block and after applying the right algorithm for a specific profile scene we deliver the data (tyre numbers, direction, and speed) to HMI[4]. The developed system is designed to perform in different environments where light and humidity can vary (ex. the case for indoor and outdoor). Figure 6 represents a final schematic about all modules composing this system and their respective functions.

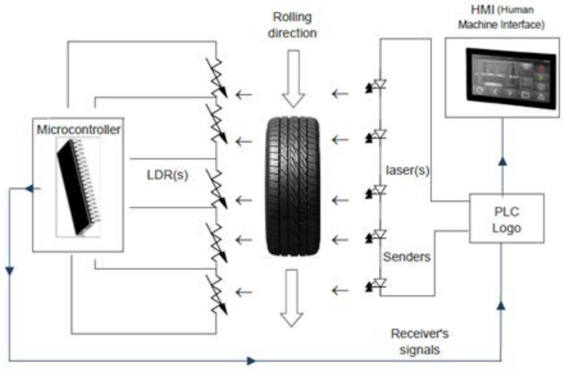

Fig. 6. Final schematic, modules combined

We designed these blocks to operate on the same voltage level thus creating good compatibility at the interface level and to safe electrical connections for operations in an open environment (minimizing ESD[5]). Each block is made of easy replaceable components that will create an easy to operate system and flexible to install.

6. MODULES, POWER ANALYSIS

With current design and configuration as one can see the whole power consumed by this system is quite low and falls into a good efficiency. Allowing it to be powered by using other alternative power sources. Whole power for this system is calculated to be about 1.655 W as we have calculated their ratings (Power calculation). Table 1. Shows how much each block uses and what is the voltage level for each of these elements.

[4] Human Machine Interface
[5] Electro-Static Discharge

Blocks	Sensory blocks	Power block	PLC	Total
Components (Details)	LDRs, Lasers	Voltage Divider(s)	IC circuit	16 pcs
Power Consumption (W)	30 mW	125 mW	1,5 W	1,655 W

Table 1. Electronic components, power consumption

Power calculations, voltage and current are based from components nominal values to improve MTBF[6] and the grade of used components is that of a normal commercial grade.

7. REAL-CONDITION TESTING

The condition on which the system is tested is on both stable light condition and variable light condition. We made it by using a simple-aluminium where pairs of each lasers and LDRs are exposed parts when tyres are moving or when environment light changes.
For the real condition testing we created the frame and transceivers positioned according to pattern specifications. Moreover, all electronics modules were installed on the same frame side to reduce the cable length and limit noises in the system (EM[7], resistance changes). As for the tyre part concerned on movement profile, we did test on such patterns:

- Linear
- Diagonal pattern
- Sinusoidal pattern

To reduce the ambient light effect, caps in tube like shapes are used for LDRs keeping them in 'dark condition 'in order to prevent the environmental light contribution.
Considering the accuracy of the system based from reliability tests done under laboratory conditions (normal room temperature, humidity, small variations of light conditions), our system performed almost with the same accuracy for different light levels and tyre movement profiles.
Results about accuracy of the system in different conditions are shown in table 2. Where calculation is based from manual tyre testing.

Movement profile	Constant speed	Fast speed	Wobbling
Accuracy per 40 tyres	100%	100%	70%

Table 2. System accuracy, different profile movements

8. DISCUSSION, FUTURE WORK

Current system design can do reliable counting in easy to use set up. Additional features are added as well such speed, tyre direction, and final log file[8]. We use this data and later on, we store it in a database. The blocks that make up the system are connected in series creating room for additional modules but probably limiting the system reliability where each block has its own task. Each block starts from the sensory block, which needs to be properly aligned in a certain distance period and the light beam, which should be concentrated in the middle point of the LDRs to overcome misplacing and ambient light contribution. Otherwise, the ambient light will create some noise in our system and could not be reliably read by next block. To solve it we are going to use pipe covers on each LDR and convex lenses placed near the end of pipe covers and in front of LDRs to make the system less sensitive to shakes. This part is very important, as the signals coming out from the LDRs are very small. Technically in range of several mA, so the circuit should be capable enough to distinguish signal change with a precise timing so that each cell can represent reliably beam interception as inputs to PLC module.

[6] Mean Time Between Failures
[7] Electro-Magnetic
[8] Data stored on PLC

For the next block, some limitations with light threshold level from boost block can happen and that is because the resistor is connected in series with LDRs where a small resistance change can bring up a big output signal for the whole system. Also considering a new configuration of the sensory block might bring good results for system reliability; as using components of Military Grade (MG) will result and increase the accuracy of this system, as that is the most part to be concerned.

The number of cells could be increased to cover a larger area and different tyre sizes. As a bigger tyre diameter would require additional lasers for this system but for this feature, it has to be designed according to pre-set dimensions that this system will measure. Future plans are to place additional lasers in the edges of central cell allowing this system to count fixed sized tyre types.

PLC, as it has been chosen Siemens Logo 0BA8, has a RJ45 interface, which enables us to control it remotely and upload the logs on the cloud. Furthermore, there are good options for data display in additional screen or touch screen modules and remote interface on the web.

9. CONCLUSION

For the current concept of this system, counting and its accuracy level are good based from tested on different environment light conditions. Moreover, the plan is to make this system perform even better on open-air conditions and make it independent of main power supply. In addition, not dependable upon variable outdoor lighting. This part will require that the blocks should be rigid and packed into a small space so that they can be also low-power consumption and cost effective. Flexibility and an easy setup approach of the system is important. Where it affects the transport and the total cost for the developed system. Further work can be done to improve HMI and compactness of the system to make it easier to transport and install.

10. REFERENCES

1. Birolini, “Quality and reliability of technical systems,” *IEEE Trans. Reliab.*, vol. 48, no. 2, p. 25055600, 1999.
2. G. Bouwhuis, “Principles of Optical Disc Systems,” *Opt. Acta Int. J. Opt.*, vol. 33, no. 6, pp. 687–687, 1986.
3. R. Vines, H. Trissell, L. Gale, and J. O’neal, “Noise on Residential Power Distribution Circuits,” *IEEE Trans. Electromagn. Compat.*, vol. EMC-26, no. 4, pp. 161–168, 1984.
4. M. Brad, B. Rishi, N. Jeffrey, P. Choon Hong, K. Dave, M. Robert, and a C. Long, “Interacting at a distance: measuring the performance of laser pointers and other devices BT - Proceedings of the SIGCHI conference on Human factors in computing systems: Changing our world, changing ourselves,” no. 4, pp. 33–40, 2002.

11. CORRESPONDING ADDRESS

Nima Sajedi
Nimasajedi@gmail.com
+37258484085
Department of Mechatronics
Tallinn University of Technology
Ehitajate tee 5,
19086 Tallinn, Estonia
http://mechatronics.ttu.ee

12. ADDITIONAL DATA ABOUT AUTHORS

1. Nima Sajedi Sabegh, MSc student
Nimasajedi@gmail.com
+372 58484085
2. Sinani Uljan, MSc student
Uljan.sinani@gmail.com
+372 58066970
3. Maido Hiiemaa, PhD, researcher
Maido.hiiemaa@ttu.ee
+372 53909109
4. Mart Tamre, PhD, professor
Mart.tamre@ttu.ee
+372 5120982