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New driver unit design and application for circular saw machine

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Abstract
Circular saw machines are used in wood working industry on a large scale in many countries. The highest usage may cause defaults on working samples such as wrong size and broken edges. In this paper, the design process of a Programmable Logic Controler (PLC) and computer aided mechanical driver unit for circular saw machine was described. Mechatronic design methodology was used in this work. The preliminary design, valuation of design requirements and the design results are finally presented. Not only the validation of the measurements on circular saw machine under human control was calculated, but also a prototype of a driver unit was also designed and calculated.

Keywords: Circular saw, mechatronic product design, designing processes, PLC, control software

1. Introduction

The use of personal computers and controllers with central processing unit in automation systems are being used more frequently. In the past, for each real time control process on systems labours were needed. Delays which were connected with human performances increased the process time and also defects. For the control process on automation systems instead of the human operators, software database and microcontroller aided controllers have been used (Bedworth et al. 1991). Nowadays critical task and operation controls done by computer communication ports and micro controllers continuously (Vitturi 2004). As a result of the microcontroller aided control systems, production cost, process time and defected products can be removed (Demmou et al. 2004; Tianfield and Unland. 2004).

Circular saw machine is a multi functional and necessary wood working machine that is used for different cutting process, pocket, canal etc. and different working on wood work samples. (Kollmann and Cote, 1984; Costes et al. 2004). When a human operator works on circular saw machine, rapid manufacturing, correct process and process planning is quite hard (United National Industrial Development Organization, 1981). According to these difficulties circular saw machine feeding driver unit was designed. Solving missing time problem, and improving production capacity were the aims of circular saw machine driver unit design. Productivity and agreeableness of this design was controlled by application results and measurements on manual controlled circular saw machine.

2. The Functional Modeling of Driver Unit of Circular saw Machine

The efficiency process on circular saw machines depends on cutting speed and feeding ratio. Circular saw machines classified in the single process machine family and working process on this machine only controlled human operator. That's the reason of production efficiency and correct product manufacturing connected with setting the correct cutting speed and feeding ratio by human operator. The traditional circular saw machine is shown on fig.1.1. In fig 1.2 the driver unit is aided by an electrical motor across the bar.

The determined correct speed and ratio are to obtain by the expert. And also technical calculations with equals are average values of manufacturing variables. Results of calculations are not applicable for each condition. Momentary requirements and conditions are not needed by human operator touchiness. This driver unit for circular saw will remove uncertain problems for manufacturing correct and complete

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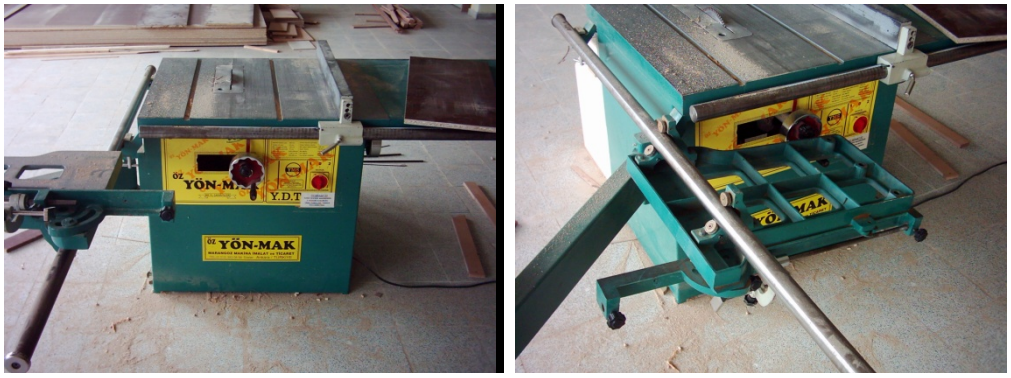
products on circular saw machine. The first work task is calculate machine variables for programming structure will be measured on the manual and driver unit aided circular saw machines.



(a) (b)

Figure 1. Circular saw machine and diver unit

2.1. Feeding ratio and cutting speed calculation

Cutting speed is changeable due to saw blade diameter and circular speed (Eger, 2003).

$$v = \frac{\pi * D * n}{1000 * 60} \left(m/sn\right) \quad (1)$$

where; D = saw blade diameter (mm)
n = circular speed (rev/min.).

feeding ratio is calculated with this formulation,

$$u_r = \frac{1000 * u}{n} \left(mm\right) \quad (2)$$

where u is feeding ratio (m/min). It is changes depending on the thickness of the chip average (h_m); feeding for each teeth (u_t), cutting depth (H) and chip length (I_S). Feeding ratio is calculated with;

$$h_m = \frac{u_t * H}{I_s} \quad (3)$$

where H = Cutting thickness (mm) (specimen tickness)

$$I_s = \frac{\pi * D * \psi}{360} \quad = \text{mm (chip length)} \quad (4)$$

Ψ angle is calculated with;

$$\psi = \arcsin\frac{2\left(H_{ws} + H\right)}{D} - \arcsin\frac{2H_{ws}}{D}\left(\deg ree\right) \quad (5)$$

where, H_{WS} = The height of the working table

The energy consumption of circular saw machine;

$$N = \frac{K * b * H * u}{60 * 102}\left(kW\right) \quad (6)$$

where b = thickness of the sow blade (mm),
H = cutting depth (mm),
u = feeding ratio (m/min),
K = specific work (kg – m/cm^3)

$$K = K_T * A_{sp} * A_m * A_d \left(kgk - m/cm^3\right) \quad (7)$$

where
K_T = specific work on cutting time (Table 2.1)
A_{sp} = Correction coefficient according to the type of wood (Table 2.2)
A_m = Correction coefficient according to the humidity (Table 2.3)
A_d = Correction coefficient according to the sharpness of saw blade (Table 2.4)

$$P = \frac{102 * N_{dr} * \eta}{v} \quad \text{(kg)} \quad (8)$$

$$N_m = N_{dr} = \frac{K * b * H * u}{60 * 102 * \eta} \quad \text{(kW)} \qquad (9)$$

$$N_m = \sqrt{\frac{N_{dr}^2 * t_c * N_i^2 * t_i}{t_c * t_i}} \quad \text{(kW)} \qquad (10)$$

N_{dr} = needed motor power,
N_i = motor power for rotating the saw blade (table 2.5)
t_c = working time for each timber specimens (sec.),
t_i = vacancy time for work changes (sec.)

Where,

Table 2.1. K_T table For the d = 60° (W=%10-15)

	u_t (mm)										
Wood type	0,05	0,1	0,15	0,2	0,25	0,3	0,4	0,5	0,6	0,7	1,0
Mild wood	10,5	8	6,4	5,5	4,9	4,5	4,1	3,9	3,8	3,7	3,4
Hard wood	16,5	13,5	11,4	9,8	8,8	8,1	7,2	6,7	6,5	6,3	6

Table 2.2. A_{sp}, Correction coefficient according to the type of wood.

Mild Wood	**A_{sp}**	**Hard Wood**	**A_{sp}**
Poplar	0,85	Beech	1,3 – 1,5
Lime	0,8	Hush	1,2 – 1,3
Pine	1	Oak	1,3 – 1,5
Spruce	0,9 – 1	Ash Tree	1,5 – 2
Alder	1 – 1,5		
Hybrid Pine	1,1		

Table 2.3. W = Correction coefficient according to the type of humidity.

Humidity condition	**Humidity (W) %**	**Am coefficient**
wet	50 – 70	1,1 – 1,15
Half dry	25 –30	1,05
Dry	10 – 15	1,0
Very dry	5 - 8	0,9

Table 2.4. Correction coefficient according to the sharpness of saw blade

t_{sh}	0	0,5	1	1,5	2	2,5	3	4
A_d	1,0	1,2	1,4	1,55	1,7	1,8	1,9	2,2

Table 2.5. (η) (N_i) measurement results

	η	**N_i**
Direct connected with motor	0,9	0,1
Connected aided with belt	0,8	0,2
Feeding mechanism and belt ‘v’ type connection	0,7	0,3

$$u = \frac{60 * 120 * N_{dr} * \eta}{K * b * H} \quad \text{(m/dk.)} \qquad (11)$$

$$P_{fc} = \frac{P_c * \sin\Psi_0 + P_d * \cos\Psi_0}{10} \quad \text{(N)} \qquad (12)$$

The normal vertical power that pushes the timber (P_n):

$$P_n = \frac{P_c * \cos\Psi - P_d * \sin\Psi_0}{10} \quad \text{(N)} \qquad (13)$$

Where, P_d = (0,2 ..... 0,8)
P_c = Saw teeth power

In this study these formulations for specified optimal feeding ratio and speed were used. As a result of

these formulations tables and schematic diagrams for feeding unit design were developed.

3. Design of the feeding unit for saw machine

It is obvious that a controller, completely implements the machine and all its operational sequences. Programmable Logic Controllers (PLC) are the most useful controller unit in automation systems. As a result Siemens (2005), S7 212 PLC CPU is used for this work. And a software support of S7 is *MicroWin* S7. Fig 2 showed Siemens S7 PLC control unit and their connection cables. Control unit consists of PLC, 8 push buttons (for each bits of plc), output connectors and output lambs.

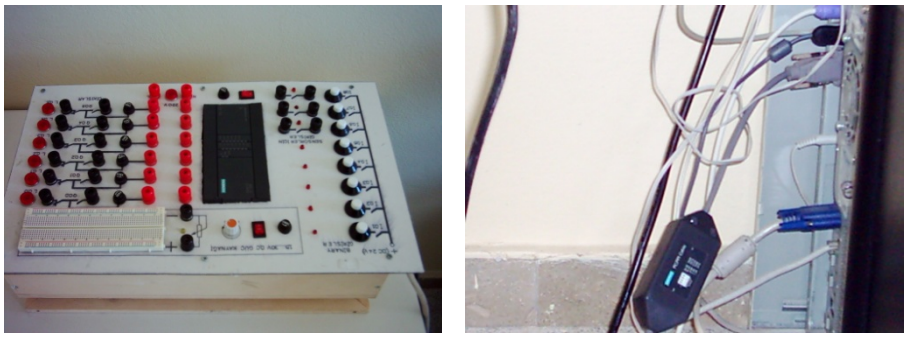
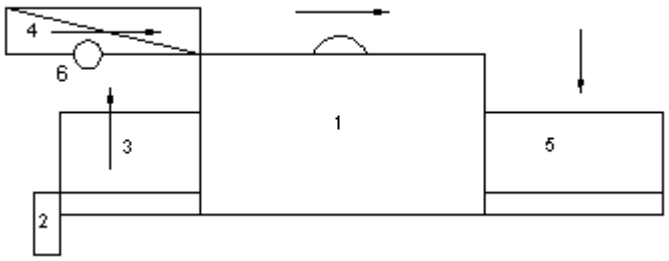


Figure 2. PLC consol and RS232 connection cord

In the study of driver design of the circular saw, the original values of machine, feature of cutting toll, type of the wood, thickness and the quantity damp in saw machine are the factors that in PLC software is changed to operation and the operations are utilized with software called *Proficut. Proficut* is the machine managing software program that utilizes cutting speed and feeding rate data coming from the machine. In addition, the program specifies optimum feed rate automatically and work piece is sent along circular saw tray. The sensor that ends of the stack unit gives us information of operation end. The stack unit starts its operation with sensor's output info. It is located according to quantity of material thickness. System is powered by an electrical motor under controlled by PLC.

System computer output data have been utilized by PLC and proficut software. Data taking with analog digital converter which transfers as in command output to feeding unit driver according to specified function on PLC. As can be seen on Figure 3.



1. Circular Saw machine and Saw blade
2. Pneumatic Cylinder
3. Feeding unit
4. Driver unit
5. Stacking unit
6. Electrical motor and PLC Connectors

Figure 3 Circular Saw Machine with driver unit schematic view

a. 2

Figure 4 1. Front side of the standard prop 2. The back side of the prop and electric motor included

Table 3.1. The specifications of the saw machine

Circular Saw Machine Specifications	
Static Table length (mm)	965*775
Table length (mm)	650*1370
Motor power (kW)	5,5
Motor reverse (rev/dk)	4200
Saw shaft specification	Direct connected with motor
Maximum saw diameter(mm)	400
Maximum cutting dept (mm)	100

4. Time Measurements and Evaluation

4.1. Method

In this study working sample methodology for collecting data were used. German work study and managing organization Refa is a methodology of working sample methodology. Refa is a standard program for work study and determinates by improving managing organization and process of the organization (Binner, H. F. 2000). Refa methodology has been focused reply to client requests, actual flexible and based on technology (Tittor, W. Et al. 2004)**.** Working sample planning, application and evaluation of this study were done by Refa methodology. Time calculations and measurements have been done with this methodology since it enables a focus for saw blade on the data collection and application.

4.2. Material

40X120 cm dimensioned, double side wood covered dry beech (w=%11) was a specimen's features. And two surfaces of the testing parts were coated with beech. Thickness of the signboard was 18 mm. Total thickness was 1.94 cm. Operation length was 120 cm. the driver unit has set with the length of this signboard. As can be seen on fig 5.

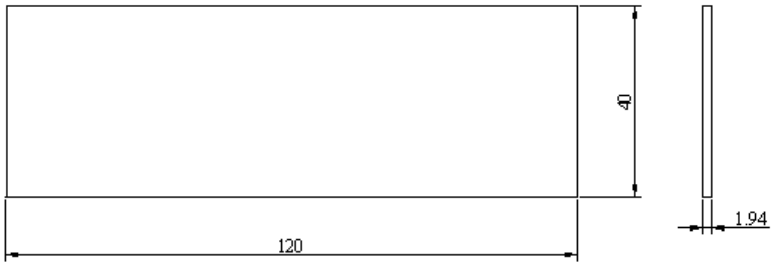


Figure 5. The dimensions of the specimens

4.3. Findings

Related to the findings of the number of observation, %95 security level and ±%5 defected products rate has been taken. 40 observations have been made. According to this 40 observations were need to calculated correct results and formulations. Finally the number of observation to take 109 which was the number of working samples in one slack were decided. Table 4.1 showed the results of the manual circular saw machine performances for 109 pcs.

Table 4.1. Statistical results of measurements values

Circular saw (specimen 120 cm)	**Results**
Total working time (sec.) tz	1655
Measurements quant. (pcs.) n	109
Average working time (sec.) $\overline{t_z}$	15,183
Total performances L	2120
Average performance	96,364
Cycle time (sec.) tz	14,63
Not required breaking time (sec.)□ tek	333
Breaking time (sec.) tek	3,06
Base cycling time (sec.) tg	17,69
Value interval total for each 5 cycle □Rz	96
Total breaking k	22
Average breaking $\overline{R_z}$	4,3636
Dispersal % z	24,67
Relative reliance interval (± %)□	2

4.3.1. PLC and computer controlled driver unit and time measurements

Starting data and maximum feeding speed for the design of the driver unit for circular saw were calculated. Because the same specified working specimen were produced on circular saw as manual one. Cutting speed calculated from eq.(1) 77 m/sec, feeding for each teeth were calculated from eq.(2) 7 mm and the cutting for each saw teeth were calculated 0,2 mm. The energy consumption on cutting were calculated from eq. (6) 13,7 m/cm^3. the needed to motor power were approximate calculated from eq. (9)'s criterions 4,2 kwatts. According these calculation results, plc ladder program was designed. Waiting and breaking times were calculated and designated on timer in PLC ladder program. The timer's hysterical delay approximately 2 mseconds.

Table 4.2. PLC controlled driver unit's measurement results

Specimen length	120 cm
Measurements quant.	109 pcs.
Total length	130,8 mt
Feeding speed	40,6 mt./min. (406 cm/min)
Working time	3,28 min.
Breaking time between working samples	29,99 sec.
Number of stacking	3 layer
Total preparing time	1,44 min.
Breaking time between working samples	1,99 sec.
Total time for break	3,58 min.
Total time for manufacturing	8,30 min.
Average time for each samples	4,57 sec.

As the practical measurements maximum feeding speed was 40,6 m/min. This value was designated on the program for starting feeding speed and decreased to the length of working sample and also daily working hour of the circular saw machine.

The maximum feeding height of the feeding and storage unit was 80 cm. Because of this, 40 working samples were produced in one stack. The number of samples was 109 pcs. The production period was separated into 3 period for 3 stacks. Loading and unloading total time was 90 seconds. Calculation and practical measurement values can be seen on table 4.2 for Plc controlled driver unit for circular saw machine.

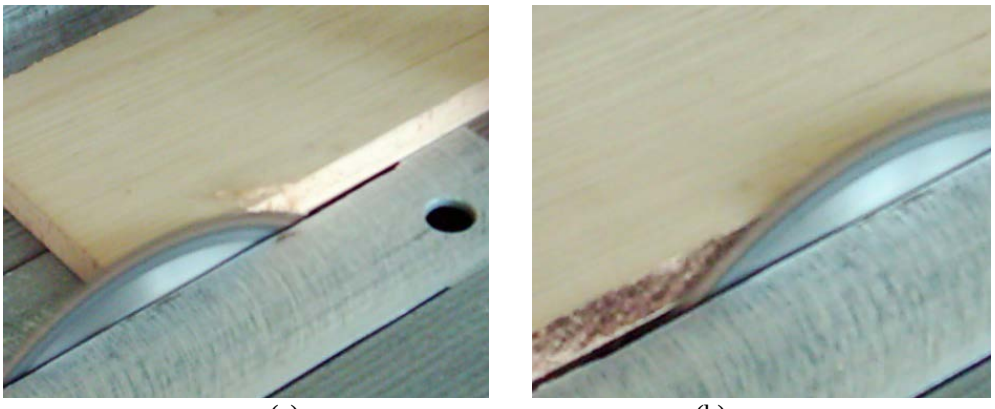
4.4. Discussions

According to the measurements of each types of circular saw machine, it can be conclude that there are some advantages and disadvantages. Accuracy, precisely and manufacturing time are important data values about working on circular saw machine. Driver unit design enables precise measurement on samples and supports short manufacturing time. Table 4.3 shows us the time and manufacturing values were obtained during all measurements on circular saw machine. Total manufacturing time results discussion between manual controlled and PLC controlled circular saw machine seen on table 4.3.

The number of defected products for PLC controlled driver unit was nearly zero. But the manual production on circular saw the number of defected products was 12 pcs. per 109 pcs. The fig 6 shows defected and correct production.

Table 4.3 Measurement result values and discussion

	Manuel Controlled Circular Saw Machine	**Circular Saw with Driver Unit Controlled by PLC**
Measurements quant.	109	
Specimen length	120 cm	
Average manufacturing time for each samples	17.69 sec.	4.57 sec.
Total time for manufacturing	32.24 min.	8.30 min.



(a) (b)

Fig6. (a). The correct production b. Defected / burned production

5. Conclusions

In the first part of this paper manual circular saw machine and circular saw machine with PLC controlled driver unit were described. Each type of circular saw machines abilities and abilities of working showed after description. We determined the design criteria and variables of the driver unit for circular saw machine. After that measurement results were presented and the performance results of both types of circular saw machine were described.

According to the measurements on manual circular saw machine, the correct and expected production is directly connected with human operator's experience and daily performance. Human factor is changeable in each condition of the working ambiance. That's why the design of the driver unit for circular saw machine solve the problems resulting from human operator and conditions of the ambiance.

The practical measurement results have shown that the performance of the driver unit of circular saw machine is better choice than the human controlled saw machine. The new design would rather save time over % 400 than the human controlled one. This showed cause the increase of production capacity nearly % 350 and also the number of defected production is decreased in % 800, since cutting speed and feeding ratio were created automatically by PLC programmed for the types of wood. The driver unit design of the circular machine is an alternative modification to the currently in used ones. Application of the driver unit for circular saw needs reasonable cost because the additional parts are only an electrical motor, their driver circuit, PLC, a computer and a PLC programmer.

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