A Mathematical Application In Continuous Metals Processing Lines

Dr. Ersen KURU

e-mail:ersenkuru@hotmail.com

Prof. Dr. Etem KÖKLÜKAYA

e-mail: ekaya@sakarya.edu.tr

Dr. Leyla KURU

e-mail: leylakuru@hotmail.com

Sakarya University, Faculty of Engineering, Department of Electrical & Electronics Engineering, 54040 Esentepe, Sakarya, Turkey

Abstract— In this article, the features of Continuous Metals Processing Lines (CMPL) are explained by examining the automation structures and it is emphasized that it is necessary to use mathematical models in this lines. As an example an automatic slow down mathematical model which is used in the entry section of a continuous line is handled. The mathematical model which is formed and how automatic slow down is established are explained by telling why automatic slow down is needed. In conclusion, the need to use mathematical models and the easiness that they brought into the Continuous Metals Processing Lines are shown.

Keywords— Continuous, Metals, Lines, Mathematics

1. NETWORK STRUCTURES CONTINUOUS METALS PROCESSING LINES

Variety of the process and number of I/O is too much in Continuous Metals Processing Lines (CMPL). Therefore network structure is necessary due to complex structure of the continuous lines. Automation design companies decide for the network structure of the PLC, RIO, protocols they use in design and the features of the processes. In addition companies modernized their network structure according to the developments in technology. [1]

1.1. Main Network System Configuration

There are two communications type of the network structure. CMPL Network structures is shown in figure 1. One of them is Cyclic Communication the other one is N:N Communication (conversation communication). Every station has special writing and reading area in cyclic communication type. So every station writes on special data areas and reads from same special data areas [2]. Example addressing areas for cyclic communication are shown in figure 3. There are Programmable Logic Controllers (PLC), Distributed Control Systems (DCS) and Operator stations (OPS) which are used in automation on network. Double ring structure is used in this network. Loop is organized again using loop-back feature when a problem occurs in the line so that reliability of the system increases [3].

1.2. Helper Network

Communication speed is not so important for some I/Os in the automation systems. Helper networks are used for this type I/Os. There are helper RIO PLCs, Operator panels, other helper PLCs which are used for packet units (welder, tension leveller, skin pass mill, oiler, etc) on the helper network. Helper RIO PLCs are using for helping main PLCs. There is communication between helper PLCs and main PLC. So helper PLCs collect some inputs and produce outputs for the control. Some times this helper PLCs are used as an interface unit for RIO. System cost goes down when using helper PLCs instead of main PLCs. Instead of using a lot of buttons, operator panels software can be used. As a result of this system cost goes also down. Double ring structure is also used in this network [2].

1.3. Operator Stations

OPSs are used for MMI and connect the main network using special interface cards. Microsoft Windows NT is used as a operating system and Intellution Fix/Dmacs are used for SCADA S/W. We can get real time trend, alarms which are already defined, TAG situation and data monitoring using OPS. OPSs can be used with PLCs and DCSs so economic system design is obtained.

1.4. Engineering Tools

It is a software that is used for online monitoring the application program, changing the program, receiving some trends, changing the parameters, downloading the program and taking the program backup. There are one server and maximum 10 terminals on the main network. X-terminals are located in pulpits, PLC room and engineering office. Thus engineers can solve some problems from every where. This means that problems can be solved in a short time when a failure occurs. As a result of this productivity of the line will be increased [3].
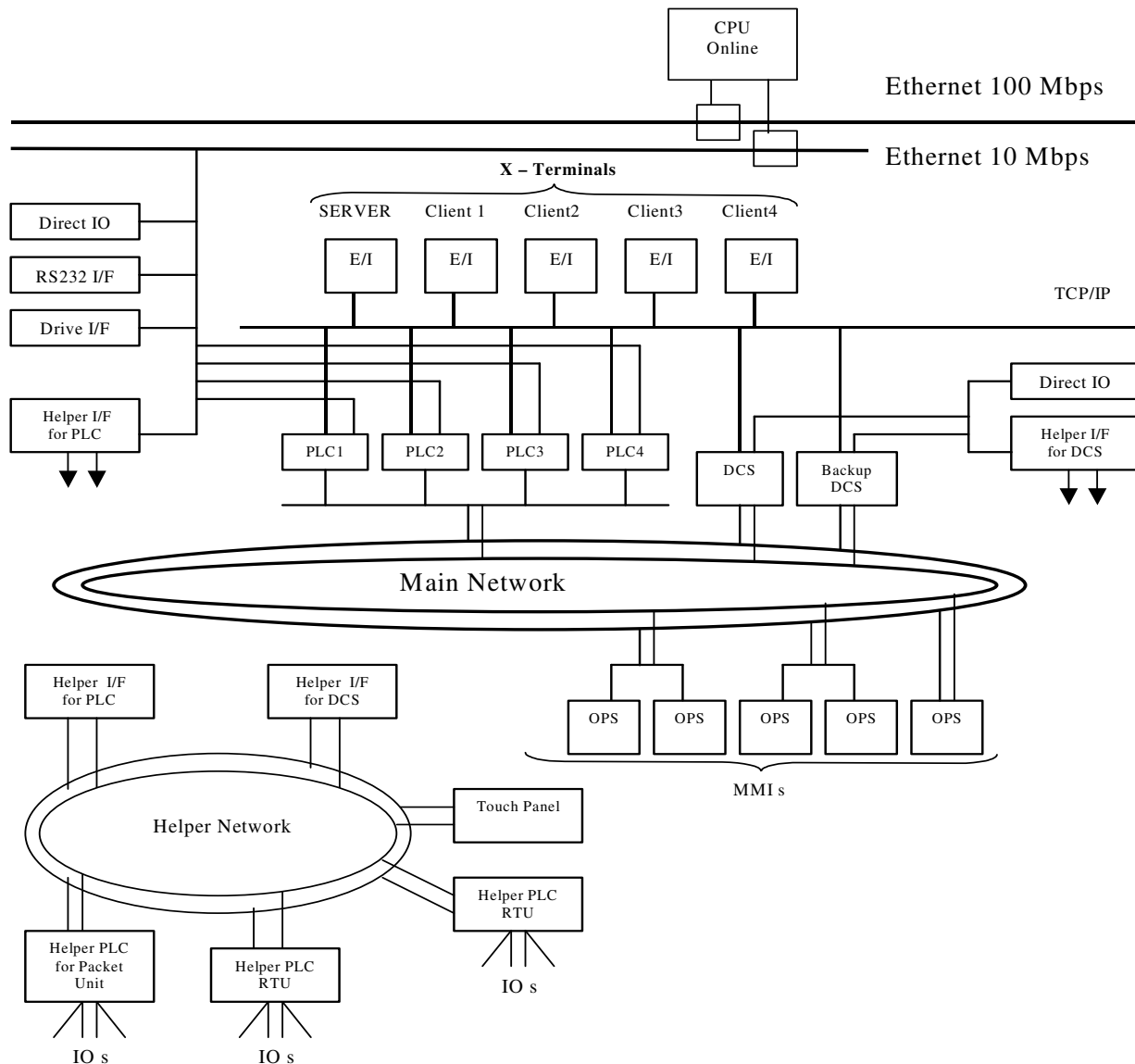
Figure1. Example Continuous Metals Processing Line Network Structures

2. ENTRY SECTION OF CONTINUOUS METALS PROCESSING LINES

Entry section line Drive control Scheme is shown in figure 2. There are some functional configuration of the Entry Automatic System. Entry line speed control, Automatic Slow Down (ASD) and stopping, coil car control, pay off reel control, loop tower position control and magnet conveyor control.

Coils are automatically settled on the pay off reel mandrel in the entry section. After that the head of the coil can be brought until the pinch roll 1 using a magnet conveyor. The head of the new coil is levelled by using leveller machine and defected parts of the head of coil are automatically cutted by using shear. Head of new coil is brought under welder machine for welding with preceding coil and start to waiting for finishing the preceding coil. So new coil is ready to production. When tail end of the preceding coil comes under the welding machine line will stop and the head of the new coil and the tail end of the preceding coil are welded so that the line will be continue. When welding process occurs entry section of continuous line is stopping. In this time furnace section is continuous because of stored strip in the entry loop. Mathematical models are necessary for all
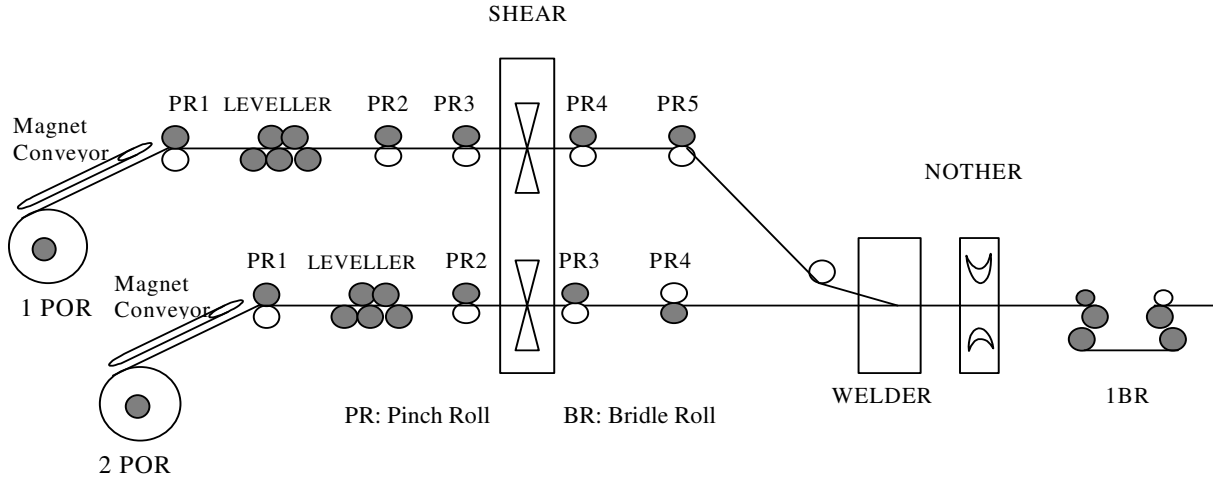
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Figure 2. Entry section line drive control scheme

operation. For example when production is continuing, coil diameter must be known for calculation of line speed and remaining coil length so that slow down of line speed time can be calculated.

In this article, a mathematical model for calculation the coil diameter which is decreasing during the process, is explained.
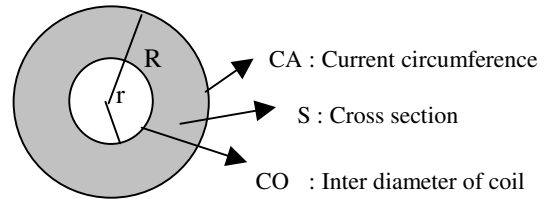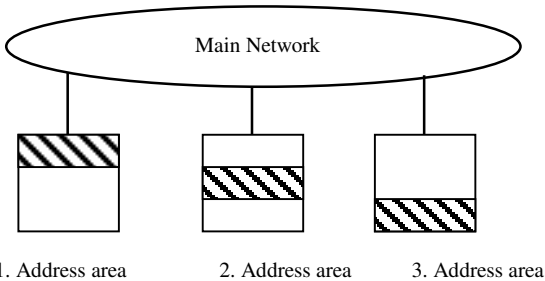

Figure 3. Addressing area for Cyclic Communication

3. ENTR SECTION AUTOMATIC SLOW DOWN CONTROL MATHEMATICAL MODEL

3.1. Description of principle

When pay off reel is working, the remaining coil length on it is always monitored. Once it reaches some preseted value, the entry section speed will automatically slow down. From the current circumference and its inter diameter of the coil, the cross section of coil can be calculated. Then through diving this cross section by strip thickness, remaining coil length can be figured out. Shape of the coil is shown in figure 4.

Figure 4. Shape of coil

$$CA = 2\pi R \Rightarrow R = \frac{CA}{2\pi} \quad \text{......(1)}$$

$$CO = 2\pi r \Rightarrow r = \frac{CO}{2\pi} \quad \text{......(2)}$$

$$S = \left(\frac{CA}{2\pi}\right)^2 \pi - \left(\frac{CO}{2\pi}\right)^2 \pi = \frac{CA^2 - CO^2}{4\pi} \quad \text{......(3)}$$

If strip thickness is "t" then remaining coil length (L) can be calculated as shown below.

$$L = \frac{S}{t} = \frac{CA^2 - CO^2}{4\pi t} \quad \text{......(4)}$$

The strip thickness is represented by "t" and it is shown in figure 5. "t" is the difference of circumference and can be expressed as shown below.

$$t = R_{n-1} - R_n = \frac{CA_{n-1}}{2\pi} - \frac{CA_n}{2\pi} = \frac{CA_{n-1} - CA_n}{2\pi} \quad \text{......(5)}$$

($CA_{n-1} - CA_n$) is represented by ΔC (The average difference between consecutive turns), then "t" can be express again as shown.

$$t = \frac{CA_{n-1} - CA_n}{2\pi} = \frac{\Delta C}{2\pi} \quad ....(6)$$

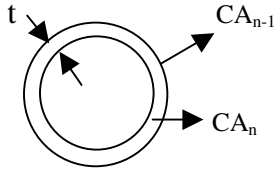

Figure 5. Strip thickness

Remaining coil length "L" can be calculated from the equation (4) and (5).

$$L = \frac{(CA+CO)(CA-CO)}{2\Delta C} \quad ....(7)$$

3.2. The Calculation Method for ΔC

Since there is some gaps between each strip sheets within the coil, the above measuring ΔC will involve error. Therefore ΔC must be averaged. The principle of average is shown in figure 6.
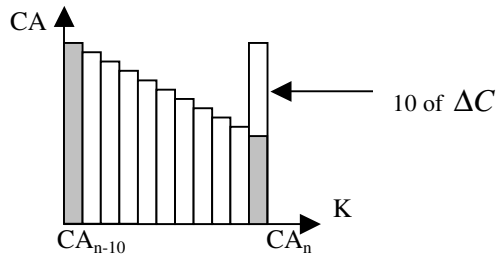

Figure 6. The principle of average

Every 10 period coil circumference is measured and this measurements differences is divided by 10 the result is the average difference between 2 tours following each other.

$$\Delta C = \frac{CA_{n-10} - CA_n}{10} \quad ....(8)$$

In order to decrease the error for ΔC and to rice its accuracy, the following method will be adopted. First the sum coil circumference for K turns has to be measured. Then the next sum of coil circumference for K turns will be measured again and so on. The principle is shown in figure 7 and figure 8.

During PLC calculates the sum of coil circumference for K turns, overflow may happen. Therefore the algorithm for

computing the sum has been changed as shown in following figure 9. Now through computing the sum of difference between the present circumference and previous one, also can be calculated.
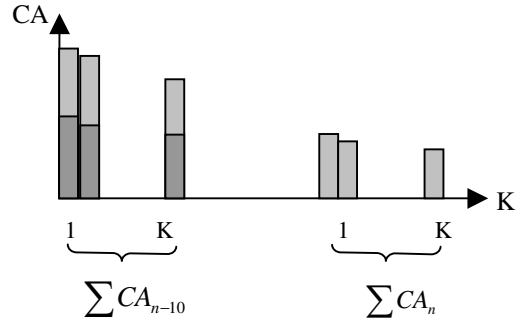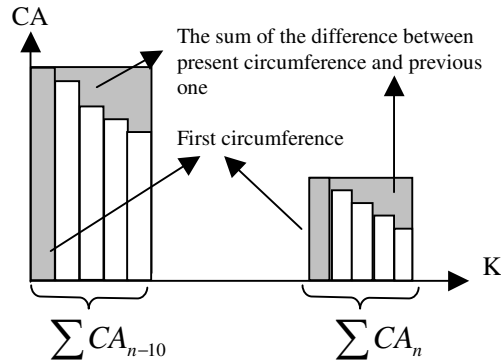

Figure 7. The principle

Figure 8. The principle of algorithm for computing the sum

$$\sum CA_n = CA_{n1} xK - \{(CA_{n1} - CA_{n2}) + (CA_{n1} - CA_{n3}) + \\ ....+ (CA_{n1} - CA_{nK})\}$$

$$\sum CA_{n-10} = CA_{n-10:1} xK - \{(CA_{n-10:1} - CA_{n-10:2}) + \\ (CA_{n-10:1} - CA_{n-10:3}) + ... + (CA_{n-10:1} - CA_{n-10:K})\}$$

In PLC the difference between last 10 sums for each K turns and the latest sum for K turns will be calculated. Then ΔC can be expressed again as shown below.

$$\Delta C = \frac{\dfrac{\sum CA_{n-10}}{K} - \dfrac{\sum CA_n}{K}}{Kx10} = \frac{\sum CA_{n-10} - \sum CA_n}{K^2 x10} \quad .....(9)$$
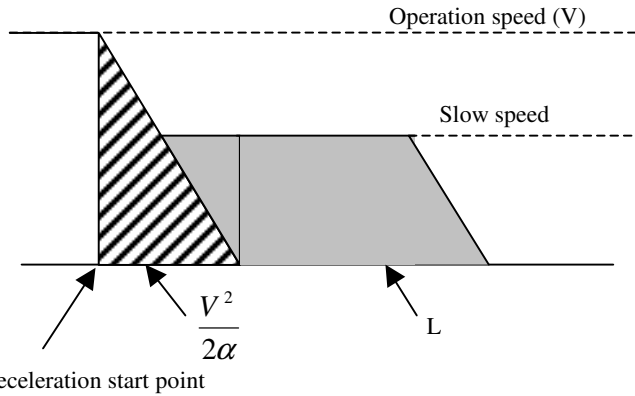
Figure 9. Detection of deceleration point

$\dfrac{V^2}{2\alpha}$: running distance needed for deceleration

L : running distance needed for slow speed

α : decelerate or accelerate rate.

RLC : remaining coil length

$$\text{RCL} = \frac{V^2}{2\alpha} + L \quad \text{………………………………………….(10)}$$

$$RLC = \frac{V^2}{2\alpha} + \frac{(CA+CO)(CA-CO)}{2\Delta C} \quad \text{………...…………(11)}$$

$$= \frac{V^2}{2\alpha} + \frac{5K^2(CA+CO)(CA-CO)}{\sum CA_{n-10} - \sum CA_n} \quad \text{…………..………..(12)}$$

Therefore when $\text{RCL} < \dfrac{V^2}{2\alpha} + L$ is true, the deceleration instruction will be output.

4. CONCLUSION

In this article, networks and automation structures which are used in Continuous Metals Processing Line has examined. Technological developments about the PLC, DCS, MMI, network structures and programming therminals are shown. Entry section line drive control scheme and automatic slow down mathematical model for entry section of a continuous line is explained as an application. In the application a continuous line used in the entry section of an automatic slow down function which is designed for a mathematical model is explained. In this article, the reason why mathematical model is used in automatic slow down, how the model is applied and what advantages it brings are also explained. Finally it is presented that network structures and mathematical models are necessary due to complex structures of the CMPL's.

5. REFERENCES

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6. BIOGRAPHIES

Ersen Kuru (1972) received his BS degree in Electrical and Electronics from Istanbul Technical University of Turkey in 1995. From 1995 to 1998 he was assistant in Abant İzzet Baysal University. He received his PHD degree in Electrical and Electronics from Sakarya University in 2003. He has been working as an Automation engineer in Eregli Iron and Steel Co. since 1998. His research interest include design of distributed computer control systems, Harmonics, SCADA and Fuzzy-logic.

Leyla Kuru (1973) received her degree in Electrical and Electronics from Istanbul Technical University of Turkey. From 1995 to 1998 she was assistant in Abant İzzet Baysal University. She received his PHD degree in Electrical and Electronics from Sakarya University in 2005. She has been working as a System engineer in Eregli Iron and Steel Co. since 1998. Her research interest include design of distributed computer control systems, MVS system and Power system stability.

Etem Köklükaya (1955) received his PHD degree in Electrical and Electronics from Istanbul Technical University of Turkey in 1990. He is a Professor in the Sakarya University. His research interest include design of distributed computer control systems, Communications, Harmonics, SCADA, Biomedical Systems and Fuzzy-logic.