KAWASAKI STEEL TECHNICAL REPORT
No.2 (March 1981)

Characteristics and Operation of Multipurpose Continuous Annealing Line at Chiba Works

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The world's first multipurpose continuous annealing line facility started operation in July 1980 at the cold rolling plant, Chiba Works, Kawasaki Steel Corporation (KSC) and achieved steel production of 15 000 t in September. Steels to be produced involves five types; high temper tinplate, low temper tinplate, non-oriented electrical steel, high-strength cold rolled sheet steel and ordinary cold rolled sheet steel. And three modes of heat cycle are applied to produce these five types of steels. In order to realize three modes of heat cycle in a single continuous annealing line, several technical innovations have been achieved in the mechanical, electrical and instrumental fields such as steel strip cooling system, intrafurnace tension control and steel strip temperature control. And a unique design and arrangement of cooling sections with multiple functions have also been developed. KSC has successfully established the production system and operation technology for producing five types of high quality steel with high productivity at low cost.

1 Introduction

Cold rolled steel is used for manufacturing many articles indispensable for our daily life, and is required to be worked into products of a wide variety of quality and broad range of sizes. For instance, tinplate and tin-free steel for making food cans are required to have the minimum thickness and high strength among cold rolled steels. Cold rolled sheet steel to be used for outer panels of cars in order to be pressed into complicated forms is required to have excellent formability. Electrical steel to be used for motor cores must have good electrical characteristics in addition to the qualities generally needed for cold rolled steel. Furthermore, in response to the increasing demand for car weight reduction in the automobile industry, the use of high-strength cold rolled sheet steel has been growing.

With the widened applications of cold rolled steel, the coil flow in cold rolling plants has become increasingly complicated, causing considerable wastage in respect of personnel allocation, coil handling, delivery time, and intermediate storage.

Recently, the continuous annealing and processing method[1-3] has been proposed as a means of solving some of these problems. This involves continuous annealing of cold rolled steel strip, followed by temper rolling and surface inspection. This method cuts down the production time from, for instance, ten days in the conventional system to just one day and simplifies the coil processing flow, offering advantage to cold rolling plants. However, since this system has production capacity generally of some ten thousands t/month, its applicability is limited only to a plant for mass-production of a few types of steel.

In consideration of this drawback, KSC planned the world's first multipurpose continuous annealing line by which several types of steels could be processed, and initiated a technical feasibility study for both the hardware and software. Consequently, the construction of the Kawasaki Steel Multipurpose Continuous Annealing Line (abbreviated as KM-CAL) was started in April 1979, after KSC's solving some technical problems associated with the multipurpose operation, including the installation of a versatile rapid cooling section. And KM-CAL has been under opera-

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tion since July 1980.

The present report concerns the outline of equipments, characteristic features, initial operation results and product quality of KM-CAL.

2 Equipments

Since the heat cycle in the multipurpose continuous annealing line should be varied depending upon the properties of the steel to be produced, it is necessary to provide more than one heat cycle for different steel products. Moreover, since the range of thickness and width of steel is wide to meet the various applications, the dimensional versatility must be taken into consideration in designing every component equipment. However, the multipurpose capability should be acquired with the minimum sacrifice of the merits of single-purpose equipment.

After repeated deliberations on this matter, a multipurpose system has been developed which is as good as single-purpose equipment with respect to productivity, quality and production cost, and suitable continuous annealing conditions have been established to be selected depending upon the product types.

2.1 Line Arrangement

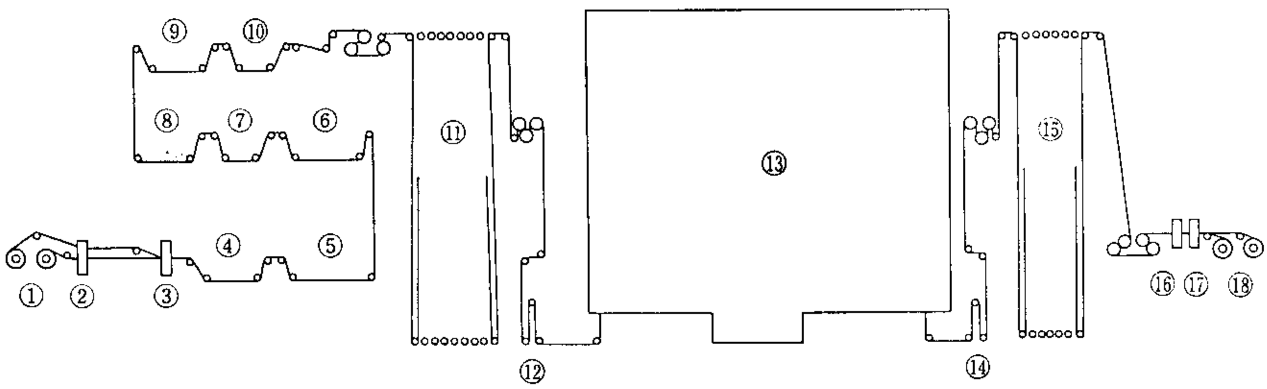
The line arrangement of the KM-CAL is shown in **Fig. 1**, and specifications for principal equipment are given in **Table 1**. The line consists of entry equipment to uncoil and clean steel strip electrolytically, central equipment to subject steel strip to specified heat cycle, and exit equipment to inspect and recoil processed steel strip. The ranges of thickness and width of steel strip to be processed were determined to cover most of the market demand. In order to reduce driving motor capacity, the line speed is switched in two steps, i.e. high/low. The high speed range is for processing high temper tinplate, low temper tinplate and electrical steel, and the low speed range is for high-strength cold rolled sheet steel and ordinary cold rolled sheet steel. The speed range is changed by using a change gear or selecting magnetic field of motors. In the KM-CAL described in the present report, the in-line skinpass mill was not installed in consideration of product mix.

2.2 Entry Equipment

The entry equipment embraces from the pay-off

Table 1 Specification of KM-CAL at Chiba Works

Item			Specification
Strip	Thickness, t	(mm)	0.15~1.2
	Width	(mm)	457~1 300
Coil	Weight	(t)	Max.21.0
	Diameter	(mm)	Max.2 134
Annual production		(t/year)	360 000
Production time		(h/year)	8 200
Line speed	Entry section	(m/min)	700(t<0.7), 250(t≧0.7)
	Center section	(m/min)	600(〃), 220(〃)
	Exit section	(m/min)	700(〃), 250(〃)
Line length	Total	(m)	150
	Furnace	(m)	70



① No.1 and 2 pay-off reels
② Shear
③ Welder
④ No.1 electrolytic cleaning tank
⑤ No.1 brush scrubber
⑥ No.2 electrolytic cleaning tank
⑦ No.2 brush scrubber
⑧ Pre-treatment tank
⑨ Rinse tank
⑩ Pre-treatment tank
⑪ No.1 looper
⑫ No.1 tension control unit
⑬ Furnace
⑭ No.2 tension control unit
⑮ No.2 looper
⑯ Down-cut shear
⑰ Snip shear
⑱ No.1 and 2 tension reels

Fig. 1 Layout of KM-CAL

reel to the first looper in **Fig. 1**. An external view of the entry equipment is shown in **Photo. 1**. The entry equipment performs the following two functions:

(1) To join cold rolled coils and feed them into the furnace at a constant speed. This function involves: two pay-off reels which uncoil cold coils alternately, a crop rejector to remove off-gauge parts automatically, a narrow lap seam welder to join the preceding strip with the following one, and a looper to store the steel strip to be fed into

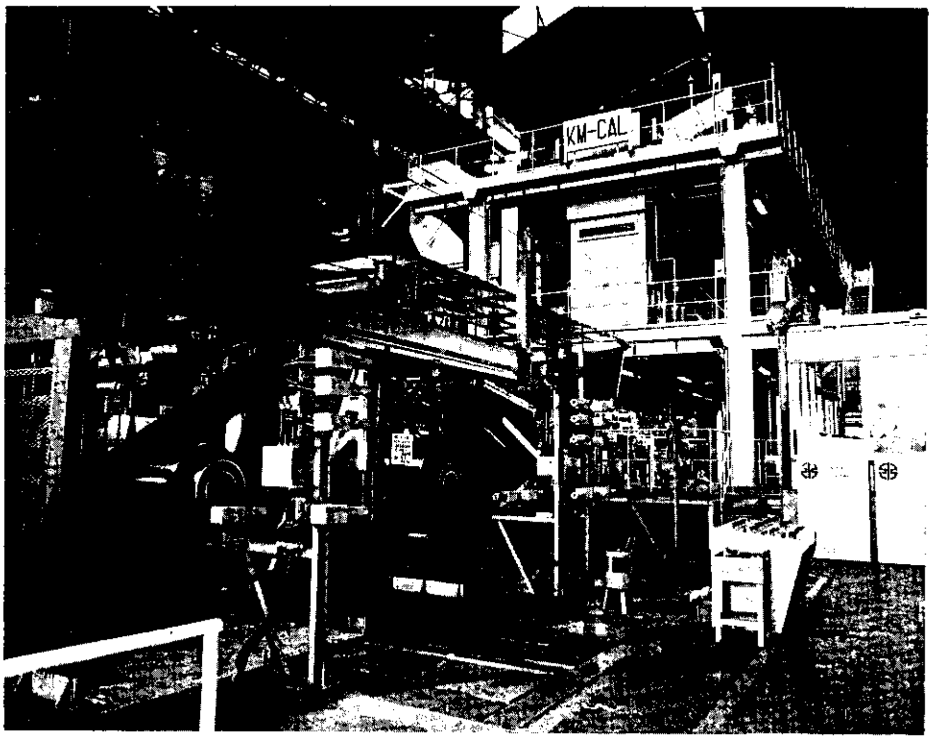


Photo. 1 General view of the entry equipment

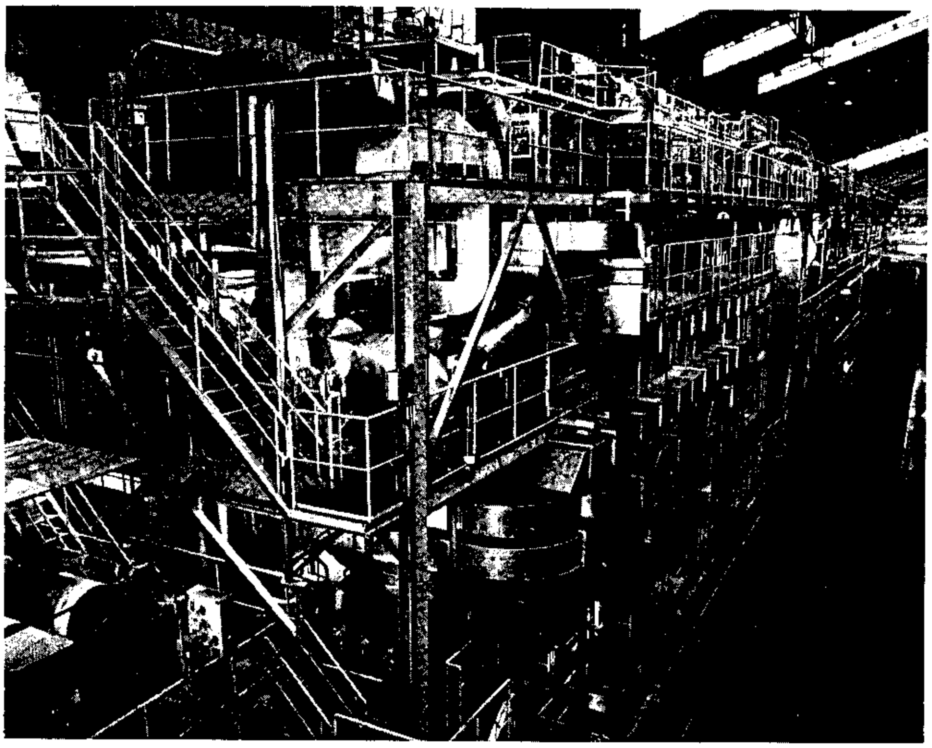


Photo. 2 General view of the central equipment

the furnace during welding.

(2) To remove rolling oil from the surface of steel strip. The cleaning equipment is designed for tinplate which required the severest surface quality. The equipment consists of two sets of each 240 kVA electrolytic cleaning tanks and brush scrubber tanks. The equipment is designed so as to obtain adequate cleaning effect of the high-speed strip passing at 700 m/min.

2.3 Central Equipment

The central equipment is a vertical furnace between Nos. 1 and 2 tension control units shown in **Fig. 1** and **Photo. 2**. It consists of five sections as shown in **Fig. 2**. Steel strip radiation thermometers for controlling the heat cycle are installed at the exit of every section except the third cooling section, and in addition two places within the first cooling section. Steering unit indispensable for high-speed processing is installed at a rate of one for each section except the first cooling section.

2.3.1 Heating section

Steel strip is heated indirectly with radiant tubes. Coke oven gas (COG) is used as fuel. The maximum heat input is 1 620 × 10^4 kcal/h, and steel strip can be heated up to 950°C. Low NO_X emission type burners of 2-stage combustion system are used which were developed by KSC for the radiant tube, achieving 30% reduction of NO_X emission in comparison with conventional one.

For the precise control of temperature, this section is divided into six zones, so that the most suitable heating pattern can be selected depending on the type of steel to be annealed. Since ceramic fiber is used as refractory and heat-insulating materials, heat accumulation in the furnace is reduced and the temperature time constant is kept small. Consequently, the dynamic control of steel strip temperature is facilitated.

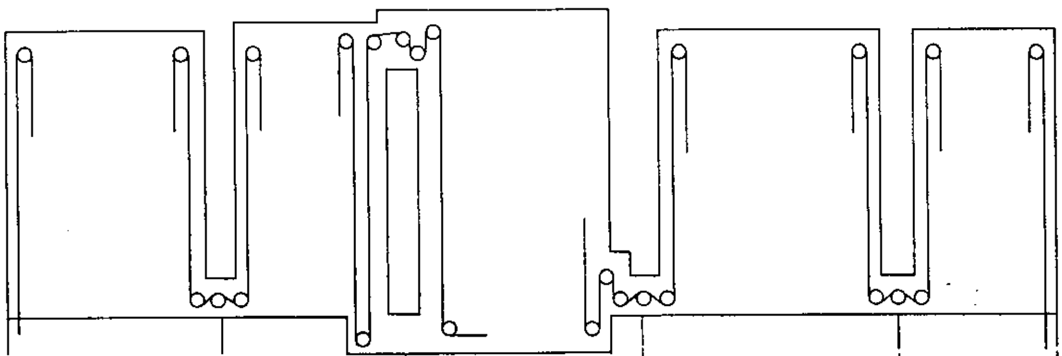
Heat contained in exhaust gas of COG combustion is recovered by recuperators provided at each burner, water heaters and air heaters. Water pre-heated by the water heaters is used for rinsing, and air pre-heated by the air heaters is used for drying in the cleaning unit, thus minimizing the waste heat of the overall system.

2.3.2 Soaking section

In order to keep steel strip at a constant temperature, radiant tube burners with maximum heat input of 250 × 10^4 kcal/h are provided. If slow cooling is required, this section can also be used for slow cooling by feeding air into the radiant tubes. For the precise control of temperature, this section is divided into two zones. Refractory and heat-insulating material is the same as that used in the heating zone.

2.3.3 First cooling section

The first cooling section can be used in any of the



Type of steel	HS*	SS*	1st CS*	2nd CS*	3rd CS*
High temper tin plate Electrical steel	Heating	Soaking	Holding	Controlled cooling	Cooling
Dual phase steel	Heating	Soaking	Rapid cooling 1	—	—
Low temper tin plate Cold rolled sheets	Heating	Soaking	Rapid cooling 2	Holding	Cooling

* HS: Heating section, SS: Soaking section, CS: Cooling section

Fig. 2 Structure of the furnace and function of each section following three modes, as shown in **Fig. 2**:

(1) Rapid cooling of strip to around room temperature, to be used for dual-phase cold rolled sheet steel with high tensile strength (commercial disignation CHLY), developed by KSC.

(2) Rapid cooling to over-aging temperature, which is used for low temper tinplate and ordinary cold rolled sheet steel.

(3) Cooling only the plenum chamber without rapid cooling steel strip.

If the distance between steel strip and plenum chamber nozzle is shortened, the heat transfer coefficient is increased and the capacity of cooling blowers can be reduced. In such a system, however, it is necessary to keep the flatness of passing steel strip at a very high level. Moreover, since CHLY is not subjected to temper rolling, the shape of steel strip should be perfectly flat after continuous annealing. Deformation of steel strip in the rapid cooling process is caused by uneven cooling attributable either to an unsuitable distribution of cooling gas flow in the direction of strip width, or to a contact of steel strip with low-temperature hearth roll. To minimize the effect of unsuitable distribution of cooling gas flow, the steel strip should be made sufficiently flat immediately before rapid cooling. Consequently the minimum outer diameter of hearth roll at the entrance of first cooling section must be precisely defined so as to minimize guttering in the direction of the strip width. Even cooling in the direction of strip width is ensured by the automatic control of crosswise cooling gas flow in reference to the temperature distribution measured in the direction of strip width. Since uneven cooling caused by the hearth rolls may occur in the initial phase of operation when the roll temperature is still low, heaters with 360 kW total capacity are provided for pre-heating the rolls so as to minimize the temperature difference between steel strip and the rolls.

2.3.4 Second cooling section

Since this section is used in the slow cooling mode for high temper tinplate and electrical steel, or in the over-aging mode for low temper tinplate and ordinary cold rolled sheet steel, the section is provided with both cooling and heating capabilities. Cooling is performed indirectly through cooling tubes at a rate of several degrees per a second. For heating, heaters with 810 kW total capacity are used. The temperature of steel strip can be held at 300 to 500°C.

2.3.5 Third cooling section

This section cools steel strip to a temperature at which no oxidation occurs in the presence of air. A general purpose gas jet cooling system is adopted.

2.4 Exit Equipment

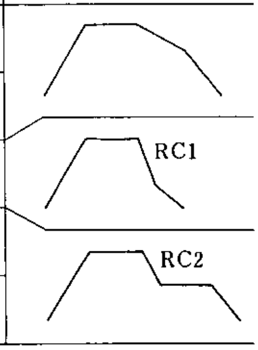
The exit equipment consists of a looper, two shears of different types and two tension reels. Since steel strip to be cut has a wide range of thickness, a snip shear for fast-fed thin gage and a down-cut shear for slow-fed thick gage are provided for cutting steel strip at the welded position.

3 Features of KM-CAL

3.1 Allocation of Functions in Furnace

Steel to be handled by KM-CAL involves five types as shown in **Table 2**, and the heat cycle is used in three modes. The most important task in designing the furnace which requires sophisticated operational technology is to securely achieve operational keyfactors laid down for respective types of steel as shown in **Table 3**, and to facilitate the execution and switching of three modes of heat cycle. An outline of the furnace in KM-CAL designed in consideration of these points

Table 2 Typical materials and heat cycles for KM-CAL

Steel type	Size range		Maximum soaking temperature (°C)	Heat cycle
	Thickness	Width		
High temper tin plate	0.15 ~0.60	600 ~1 000	700	
Electrical steel	0.35 ~0.70	800 ~1 100	900	
Dual phase steel	0.60 ~1.2	600 ~1 300	900	RC1
Soft temper tin plate	0.15 ~0.60	600 ~1 000	750	RC2
Cold rolled sheets	0.40 ~1.2	600 ~1 300	850	

RC:Rapid cooling

Table 3 Key factors and operational measures for each material

Steel type	Key factor	Measure
High temper tin plate Electrical steel	Stable high speed operation	①Optimization of hearth rolls in terms of profile and surface quality ②Accurate tension control in the furnace ③Optimum arrangement of hearth rolls
Dual phase steel Cold rolled sheets	Cooling rate control	①Application of adjustable cooling system using gas jet ②Development of radiation thermometer with high accuracy ③Accurate computer control
	Abundant cooling capacity	Development of gas jet cooling system with high efficiency
Low temper tin plate	Strip shape control during rapid cooling	Low tension operation in the furnace
	Stable high speed operation	Same as the uppermost column

is shown in **Fig. 2**. A number of innovative attempts have been made, such as designing of two functions of cooling and holding at the first and second cooling sections. For instance, the first cooling section is so designed that the gas jet fans can be used selectively for rapidly cooling the steel strip or for holding the steel strip temperature. In the latter case, the gas jet fans are used for cooling the plenum chambers alone to prevent their thermal deformation.

3.2 Adjustable Cooling System

The cooling rate for CHLY must range from 30 to 50°C/s as shown in **Fig. 3**[4] in order to obtain satisfactory mechanical properties. For securing cooling rate in this range with 1.2 mm thick steel strip, the mean heat transfer coefficient of gas jet cooling is required to be 250 kcal/m²•h•°C, which is substantially greater than 30 to 100 kcal/m²•h•°C of the conventional gas jet cooling. The greater the cooling rate of steel strip is, the more frequently deformation of steel sheet may occur. Since deformation of steel strip increases uneven cooling, a kind of vicious circle sets in to lower operation rates.

In order to solve this problem, KSC constructed a full-size experimental model of the furnace in cooperation with Mitsubishi Heavy Industries, Ltd. (to be abbreviated as MHI), the furnace builder for KM-CAL, to investigate the gas jet cooling of steel strip. The cooling system of KM-CAL was designed on the basis of the results obtained with this experimental system. The cooling capacity of KM-CAL obtained in

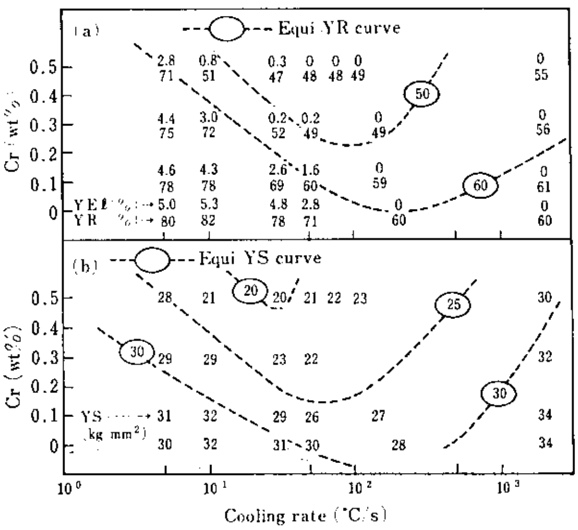


Fig. 3 Effect of cooling rate and Cr content on (a) yield point elongation and yield-to-tensile strength ratio, and (b) yield strength

actual operation was nearly identical to that of the test system, as shown in **Fig. 4**. Thus, it became possible to cool steel strip rapidly while keeping it in good shape. While HN gas (H_2: 7% and N_2: 93%) was used as the atmospheric gas in the experimental model, it is possible to increase hydrogen concentration in the actual system for the purpose of energy saving and improving the cooling efficiency.

On the other hand, with regard to rapid cooling

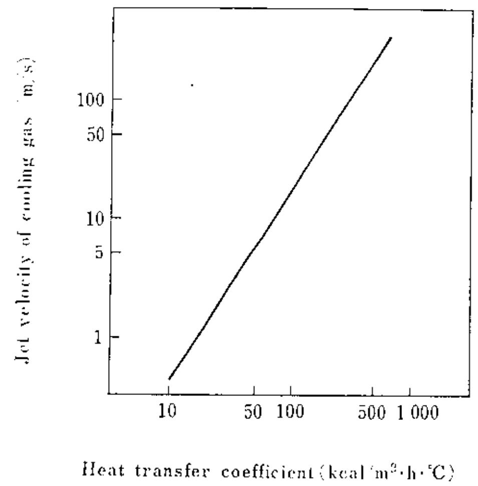


Fig. 4 Cooling capacity of gas jet obtained by test equipment

after soaking, the cooling system is required to control the cooling capacity for a wide range because the thickness of steel strip has an extremely wide range as shown in **Table 2**, and different products require different relationships between cooling rate and processing speeds to secure necessary mechanical properties.

In the adjustable cooling system adopted in KM-CAL, the rapid cooling process involving so many variables is controlled with high accuracy by a process computer. An outline of the control system is shown in **Fig. 5**. The operational conditions for the first cooling section are determined by particular cooling rate and processing speeds required for steel strip to be cooled rapidly. For instance, in the case shown in

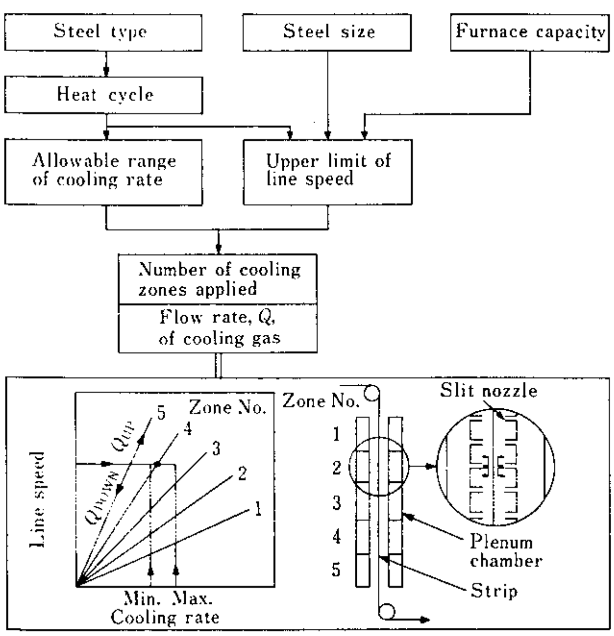


Fig. 5 Schematic diagram of adjustable cooling system

Fig. 5, four zones are used, and the flow of cooling gas is about 70% of maximum capacity.

3.3 Furnace with Excellent Stability at High Speed

The most difficult problem in processing high temper tinplate at a high speed is to prevent steel strip from mis-tracking in the furnace. On the basis of operation with the existing CAL (maximum processing speed: 550 m/min, capacity: 3×10^4 t/month), the maximum processing speed in KM-CAL was set to 600 m/min, and the following measures were taken to minimize mis-tracking of steel sheet within the furnace.

(1) Each hearth roll profile was designed in consideration of heat crown caused by the temperature distribution at the hearth roll during the operation.
(2) In order to reduce slip between the hearth roll and steel strip, the central area of hearth roll surface was subjected to special treatment[5] so as to increase the friction coefficient to the extent that buckling is not induced.
(3) Hearth rolls were provided wherever steel strip tends to hang slack by its own weight[6], so as to facilitate the control of strip tension in the furnace.
(4) A control system for strip tension in the furnace was developed to obtain stable strip tension by absorbing thermal expansion/contraction of steel strip and plastic elongation under tensile stress. Through these measures, KM-CAL has succeeded in processing high temper tinplate at a rate of 600 m/min in three months after start of operation.

3.4 Automatic Control System for Strip Tension in Furnace

The control of strip tension in the furnace gives serious influence on mis-tracking of fast-running steel strip and deformation of rapid-cooled steel strip. Particularly, in the case of multipurpose continuous annealing line with diversified steel strip dimensions, it is an important task to improve the accuracy of the strip tension control.

On the basis of experiments with the existing CAL and theoretical analysis, an innovative control system for strip tension in the furnace has been developed with a master roll installed within the furnace for providing a reference for speed control as shown in **Fig. 6**, and with intrafurnace bridle devices installed at the entrance and exit of the first cooling section. With this system a section where steel strip is heated to expand can be separated at the master roll from a section where steel strip is cooled to contract, and the strip tension in two sections can be controlled independently. Hence, the strip tension in the furnace can be controlled properly with high accuracy, in combination with the variable voltage and variable frequency (VVVF) system adopted in the drive motors for the

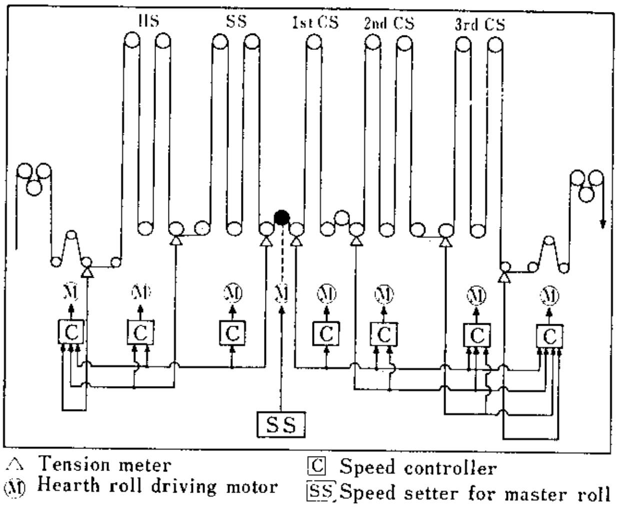


Fig. 6 Schematic diagram of automatic tension controller

hearth rolls. Furthermore, the bridle devices installed at the entrance and exit of the first cooling section enable to control the strip tension in this section at a lower level independently from that in other sections. KM-CAL is the first case of adopting the VVVF system in the vertical continuous annealing furnace characterized by tight strip tension, and this has brought out the merits of low cost and easy setting of desired gradient on strip tension within a single section.

3.5 Automatic Control System for Strip Temperature

Mechanical properties of cold rolled sheet steel are determined by the chemical composition of steel, hot rolling conditions, cold reduction rate and annealing conditions. Hence, annealing is one of the important processes for obtaining aimed mechanical properties. In order to achieve perfect annealing in the continuous annealing line, it is essential to detect the exact temperature of running steel strip. For this purpose, some models of radiation thermometer, suited for KM-CAL, were developed and their accuracy was verified by experiments with the existing CAL.

The control system for steel strip temperature adopted in KM-CAL is shown in **Fig. 7**. In KM-CAL which has a wide load range, it is an important means for reducing inadequately annealed portion of strip to grasp the dynamic characteristics of the furnace and to control the steel strip temperature properly in response to load changes. In this system, an emphasis is placed on the dynamic control.

3.6 Roll

Items to be studied on the rolls required for the multipurpose continuous annealing line are listed in **Table 4**. Rolls adopted in KM-CAL are based on the results of studying these problems, and exhibit satisfactory performance in actual operation.

4 Operation of KM-CAL

The output of KM-CAL has increased smoothly since the start of full operation. However, since the data obtained over these three months are insufficient to analyze the productivity, energy comsumption and merits of KM-CAL, the present report concentrate

Table 4 Research subjects of rolls in multipurpose CAL

Type	Factor	Related subjects to be presented	
		$t \leqq 0.4$	$t > 0.4$
Hearth rolls	Diameter		①Guttering ②Fluting ③Degradation in mechanical properties of strip
	Profile	Mis-tracking	
	Surface quality	Mis-tracking	Pick-up
	Material quality		Pick-up
Bridle rolls	Material quality	①Slip ②Roll abrasion	
Other rolls	Diameter		Fluting
	Profile	Mis-tracking	
	Surface quality	Mis-tracking	

t: Strip thickness in mm

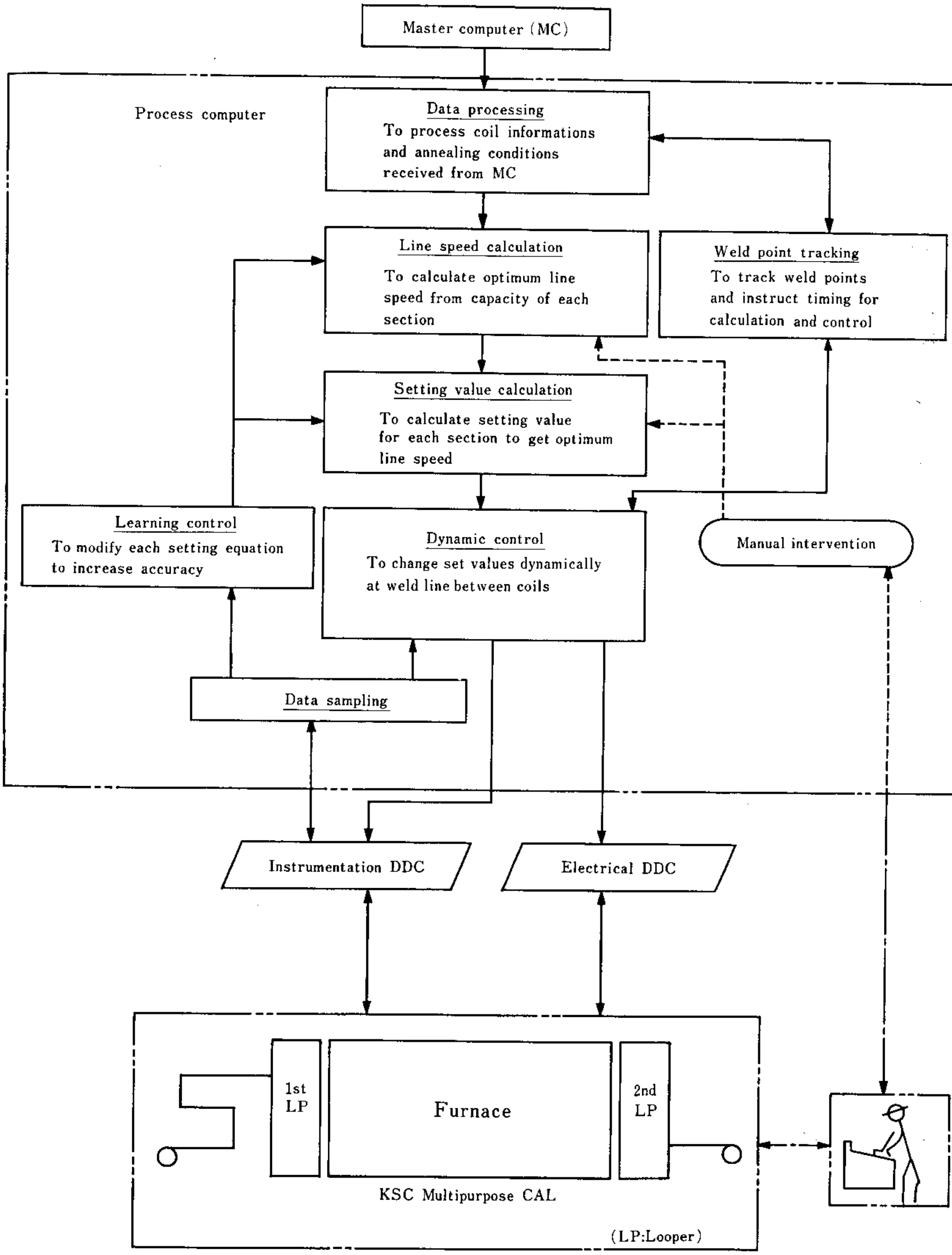


Fig. 7 Schematic flow diagram for dynamic control of strip temperature

upon the situation immediately after start of operation and the experience with the newly developed equipment.

4.1 Production Achievement

Changes in the monthly production amount of various types of steels and in the maximum processing speed of high temper tinplate are shown in **Fig. 8**. The output of every type has increased smoothly, and the processing speed of high temper tinplate has also increased with every production period, attaining stable operation at the specified maximum speed in the third month after start of operation.

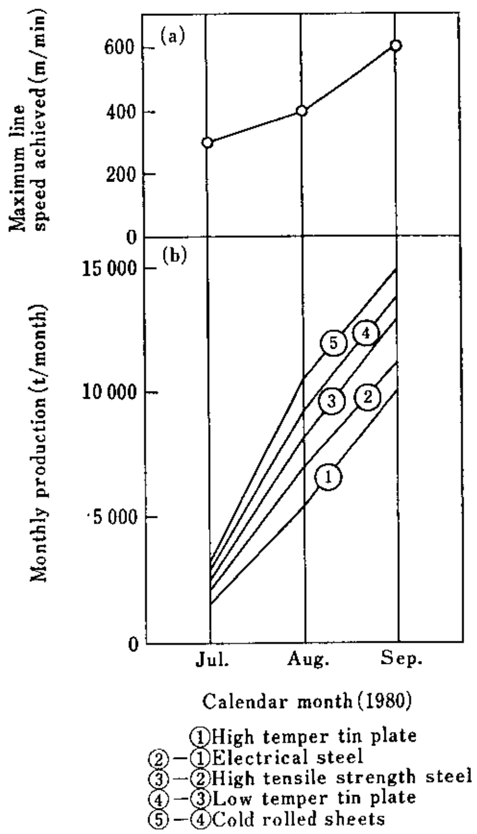


Fig. 8 Start-up performance of (a) maximum line speed for high temper tinplate and (b) monthly production of each type of steels

4.2 Experience with Newly Developed Equipment

The performance of most of the new equipment adopted in KM-CAL was confirmed throughout the trial operation and three-month commercial operation. The experience with major equipment will be described below.

(1) Furnace section
Functions of the first and second cooling sections were successfully changed over, permitting three modes of heat cycle in a single continuous annealing furnace. The VVVF, which had required elaborate adjustment in the trial operation, demonstrated the merits described above to the maximum extent, and high-speed processing of high temper tinplate was achieved with relative ease.

(2) First cooling section
The first cooling section, in which a number of new technologies had been introduced with regard to gas jet, provided satisfactory results in the cooling capacity and the shape of cooled steel strip. These results provide the effectiveness of our designing technology regarding the layout of the cooling unit, equipment capacity and gas jet nozzle shape.

(3) Automatic control system for strip tension in furnace
With the improved accuracy of control of strip tension in the furnace, high temper tinplate of 0.220 mm thickness was processed at a specified

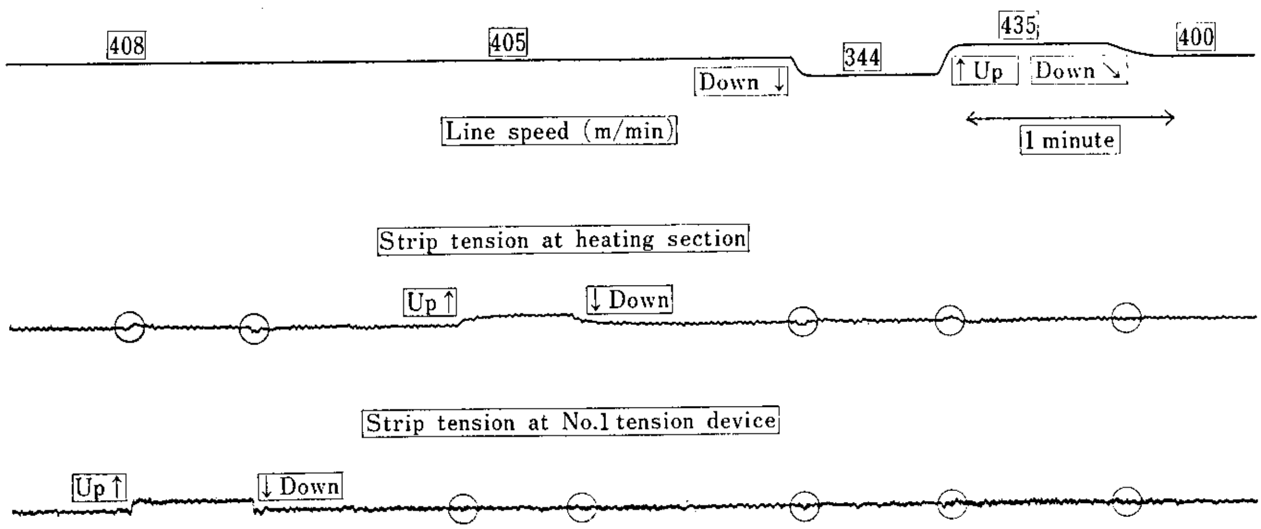


Fig. 9 Fluctuation of strip tension when strip tension or line speed changed

maximum processing speed of 600 m/min. In the near future, it will become possible to process high temper tinplate of 0.150 mm thickness. On the other hand, low temper tinplate of 0.200 mm thickness was readily produced by reducing the strip tension in the first cooling section in comparison to that in other sections and with cooling rate of 40°C/s. These feats have been achieved by controlling the strip tension in the furnace within ±5% of the specified value as shown in **Fig. 9**.

(4) Automatic control system for strip temperature
Radiation thermometers installed at respective sections except for the third cooling section provided good results with various types of products, with automatic setting of proper emissivity of strip surface. The automatic control system for strip temperature is under normal operation as initially planned, except for a part of dynamic control which is still under test.

5 Product Quality by KM-CAL

5.1 Operating Conditions

The optimum operating conditions to meet quality requirement for every type of steel to be processed by KM-CAL are described below.

(1) Composition of steels
Typical chemical compositions of the steels are shown in **Table 5**. Chemical composition of low temper tinplate (T-3) is the same as that of high temper tinplate (T-4), and chemical composition of ordinary cold rolled sheet steel is the same as that of batch-annealed aluminum killed sheet steel. As an example of high strength cold rolled sheet steel, the composition of dual-phase steel CHLY is given in **Table 5**.

(2) Heat cycle
Typical heat cycles for various types of steels are shown in **Fig. 10**. The heat cycle for high temper tinplate is the same as that in the conventional CAL without over-aging treatment. For electrical steel, higher soaking temperature is applied than in the case of other types of steels. The heat cycle for low temper tinplate and ordinary cold roll sheet steel includes rapid cooling and over-aging treatment. The heat cycle for CHLY is characterized by rapid cooling to room temperature after soaking.

5.2 Quality of Products

(1) High temper tinplate
The hardness of tinplate produced by KM-CAL is shown in **Fig. 11**. As with the existing CAL for high temper tinplate, the required quality were secured satisfactorily. The tin plating characteri-

Table 5 Typical chemical composition of each material

Steel type	Chemical composition (%)								Aimed quality
	C	Si	Mn	P	S	N	Al sol	Others	
High temper tin plate	0.04 ~0.06	≦0.03	0.25 ~0.35	≦0.020	≦0.020	≦0.004	0.04 ~0.06	—	T-4
Low temper tin plate	0.04 ~0.06	≦0.03	0.25 ~0.35	≦0.020	≦0.020	≦0.004	0.04 ~0.06	—	T-3
Dual phase steel	0.03 ~0.05	≦0.05	1.2 ~1.3	≦0.020	≦0.020	≦0.004	0.02 ~0.06	[Cr] 0.45 ~0.55	40 kgf/mm² class (CHLY40)
	0.08 ~0.10	1.00 ~1.20	1.6 ~1.8	≦0.025	≦0.020	—	0.02 ~0.08	[Nb] 0.030 ~0.050	80 kgf/mm² class (CHLY80)
Cold rolled sheets	0.02 ~0.04	≦0.03	0.30 ~0.35	≦0.020	≦0.020	≦0.003	0.02 ~0.04	—	JIS SPCC class

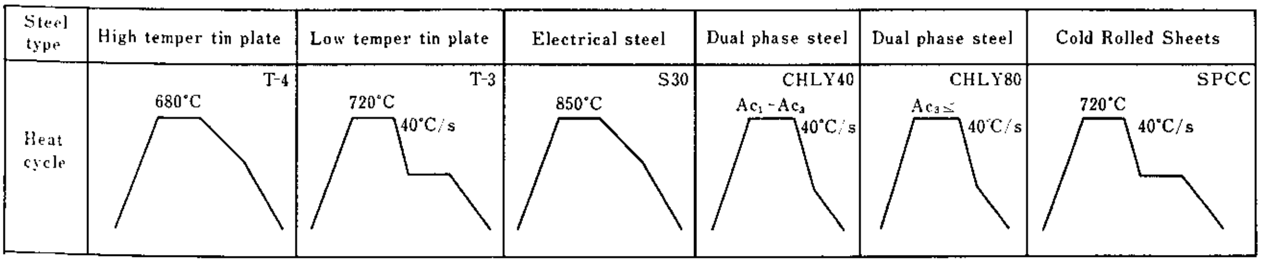


Fig. 10 Typical heat cycles for each type of steels

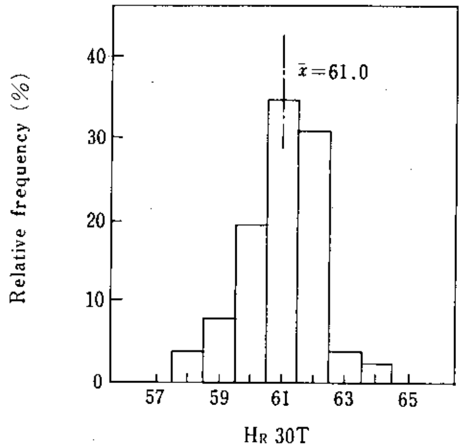


Fig. 11 Hardness distribution of high temper tinplate (T4-CA)

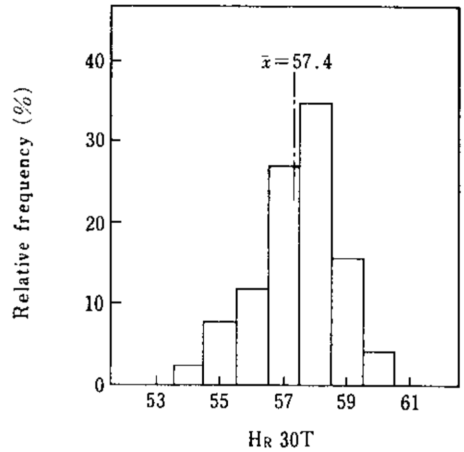


Fig. 12 Hardness distribution of low temper tinplate (T3-CA)

stics were likewise good.

(2) Low temper tinplate

Low temper tinplate was produced from the materials shown in **Table 5**. The hardness of low temper tinplate produced by KM-CAL is shown in **Fig. 12**. Products were homogeneous with very small fluctuation in hardness. The tin plating characteristics were at the same level as that of high temper tinplate, and the corrosion resistance was superior to that produced by batch-annealing.

(3) Electrical steel

While KSC had been producing electrical steel mostly at its Fukiai Plant, Hanshin Works, with the commencement of the highly productive KM-CAL system, a part of the production was transferred to Chiba Works, effectively reducing the production cost. The product types are fully processed non-oriented electrical steels, equivalent to JIS S60–S30 (AISI M-47) and semi-processed electrical steel, equivalent to AISI M-36.

(4) Dual phase cold rolled high strength steel, CHLY

The mechanical properties of CHLY 40 and 80 produced by KM-CAL are shown in **Fig. 13** and **Table 6**, respectively. The chemical composition is given in **Table 5**. The yield point of CHLY 40 (**Fig. 13**) is as low as 19.6 kgf/mm², yield to tensile strength ratio, YR being below 45%. In the case of 80 kgf/mm² class steel (**Table 5**), the YR and the elongation are 48.4% and 20%, respectively.

The flatness of CHLY after rapid cooling by KM-CAL before temper rolling is the same as that of ordinary batch-annealed steel sheet after temper rolling.

Table 6 Mechanical properties of dual phase steel

Brand	YS (kgf/mm²)	TS (kgf/mm²)	El (%)	YEl (%)	YR (%)
CHLY80	42.0	86.7	22.1	0	48.4

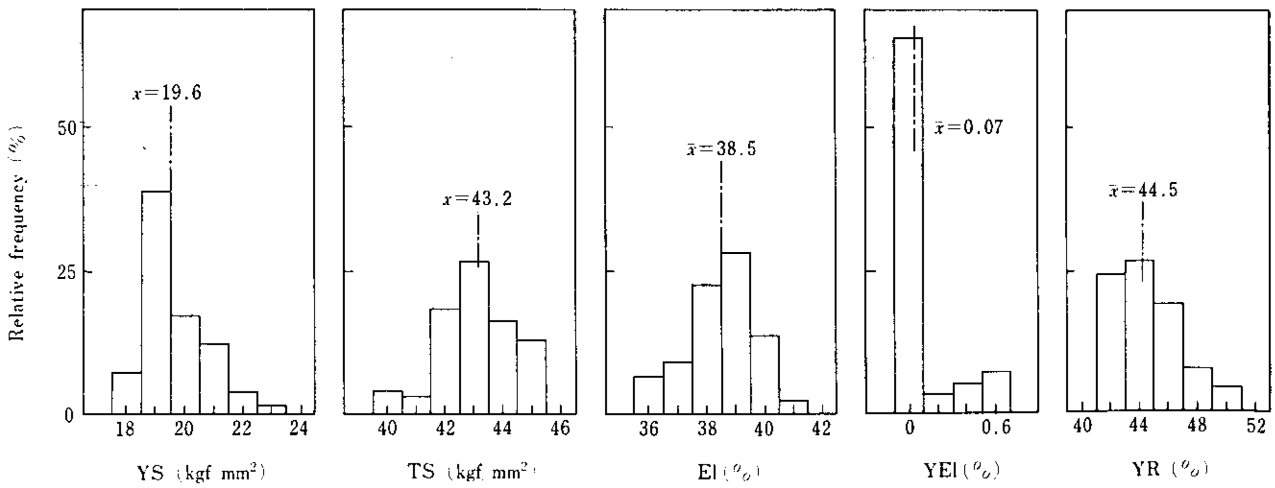


Fig. 13 Distribution of mechanical properties of dual phase steel (CHLY 40)

For this reason, KSC's CHLY, which is free from yield point elongation phenomenon immediately after continuous annealing, permits omission of the temper rolling process, if surface roughness is regulated in advance.

(5) Ordinary cold rolled steel sheets

The mechanical properties of JIS SPCC class steel sheet produced by KM-CAL are shown in **Table 7**, in comparison with the batch annealed steel sheets. The steel produced by KM-CAL has better values than the batch-annealed steel, like that produced by the CALs with over-aging treatments reported previously[7,8]. The chemical composition and mechanical properties of super deep drawing steel developed[9] by KSC specially for continuous annealing are shown in **Table 8**. The mechanical properties were the same as or better than those of any type of steel being produced commercially ensuring prospective demands in the future.

Table 7 Mechanical properties of JIS SPCC class cold rolled sheets

	YP (kgf/mm^2)	TS (kgf/mm^2)	El (%)	$\bar{r}$ value	Type of material
KM-CAL	21.4	32.3	44.0	1.69	Continuously cast slab
Batch annealed	21.9	33.2	44.5	1.33	Capped ingot

Table 8 Chemical composition and mechanical properties of deep drawing quality cold rolled sheets

Chemical composition (%)	C/0.003	Si/0.01	Mn/0.12	Al/0.033	Nb/0.04
Mechanical properties	YP (kgf/mm^2)	TS (kgf/mm^2)	El (%)	$\bar{r}$ value	Annealing
	14.1	31.0	49.2	2.4	850°C×2 min

6 Conclusions

KSC successfully fulfiled smooth operation of KM-CAL in as short a period as three months, and achieved the results as planned in respect to both operation and quality.

(1) High temper tinplate was processed as fast as 600 m/min through the improved hearth roll and the highly stable control of strip tension in the furnace.

(2) As for low temper tinplate, T-3 of thickness to 0.20 mm was produced through the improved gas jet equipment and the low-tension operation at rapid cooling section ensuring excellent quality.

(3) High temperature processing of electrical steel was attained in a vertical furnace.

(4) Dual phase, high tensile strength cold rolled sheet steel, CHLY, were produced with excellent mechanical properties through the highly accurate control of soaking temperature and cooling rate. The flatness of steel sheet was equal to that of temper-rolled, batch-annealed steel sheets, through the uniform cooling in the direction of strip width and low-tension operation in the process of rapid cooling.

(5) The JIS SPCC class ordinary cold rolled steel sheet showed mechanical properties equal to or better than those of batch-annealed steel sheets. The super deep drawing steel sheet having excellent press formability was produced from extra-low carbon steel.

As described in the above, KSC has established a new continuous annealing technology through the construction and operation of the originally-developed KM-CAL. Furthermore, KSC is planning the construction of new multipurpose CALs which can be employed in various steelworks and which will also be able to process new products under development, on the basis of the technology obtained.

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