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Automatic Machining System of Mechanical Testing Process

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Automatic Machining System of Mechanical Testing Process*


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1 Introduction

In the Japanese steel industry, a considerable degree of automation and computerization of manufacturing facilities has been achieved, with the aim of improving productivity and product quality. The automation of the mechanical testing, however, has lagged and has only recently been undertaken.[1] Mizushima Works began implementation of full-scale automation and computerization of mechanical testing with the aims of improving testing productivity and shortening the time required for test. After two years of study and two further years of construction, the Mechanical Testing Center was completed in July 1985.

This report describes the development of an automatic gas cutting machine, equipped for automatic stamping of special script marks and autodeburring, and an automatic handling system for test specimens.

2 Outline of Mizushima Mechanical Testing Center

The aims of the construction of the Mechanical Testing Center were reduction in personnel, improvement in both productivity and reliability, and shortening of the test process. To achieve these targets the mechanical test rooms were integrated, automated equipment and on-line and real-time information processing by an exclusive-use computer were introduced. The guiding philosophy of this project was overall systematization of both hardware and software as a basis for the complete automation of mechanical testing.

The Mechanical Testing Center is responsible for the final inspection of the quality characteristics of steel products manufactured by the Works. The operation process in this work is broadly divided into: (1) cutting, in which sample plate taken from steel material is cut into sample blocks by gas-cutting or shearing, according

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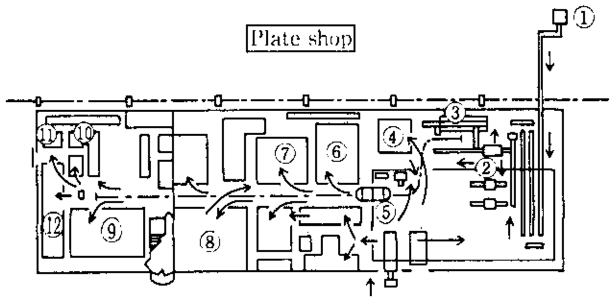


① Sample cutting machine
② Automatic gas cutting machine
③ Spare sample storage
④ Automatic punching device
⑤ Automatic transfer car
⑥ Tensile specimen milling machine
⑦ Charpy impact specimen machining
⑧ Heat treatment furnace
⑨ Tension testing machine
⑩ Hardness testing machine
⑪ Bend testing machine
⑫ Charpy impact testing machine

Fig. 1 Layout and material flow in the Mechanical Testing Center[2)]

Table 1 Newly introduced equipment and computer linkage condition

	Name of equipment		Quantity	Computer linkage	Remarks
Sample cutting and machining	Automatic stamping machine		1	○	
	Automatic gas cutting machine		1	○	R×2
	Automatic punching device		1	○	
	Tension test specimen machining	Rectangular type	1	—	
		Round type	1	—	R×1
	Charpy impact specimen machining		1	○	R×1
Mechanical testing and sample handling	Automatic tension testing machine		4	○	200 tf 50, 20, 10
	Automatic Charpy impact testing machine	JIS type	1	○	R×1
		ASTM type	1	○	
	Automatic hardness testing machine	Twin-rockwell	1	○	
		Vickers	1	—	
		Micro-vickers	1	—	
	Automatic transfer car		1	—	
	Automatic spare sample storage		1	—	

R: Robot

to required test items, (2) specimen machining, in which sample blocks are processed into specified specimen shapes, (3) material tests, and (4) judgment.

The layout of the Center and the handling of test materials are shown in **Fig. 1**. Great importance is attached to efficient transportation of the mother material from which samples are taken. To facilitate direct conveyor-transportation of the material types most frequently handled and, in addition, those of particularly great unit weight, a belt conveyor is positioned adjacent to the plate mill. Other types of material are transported by truck.

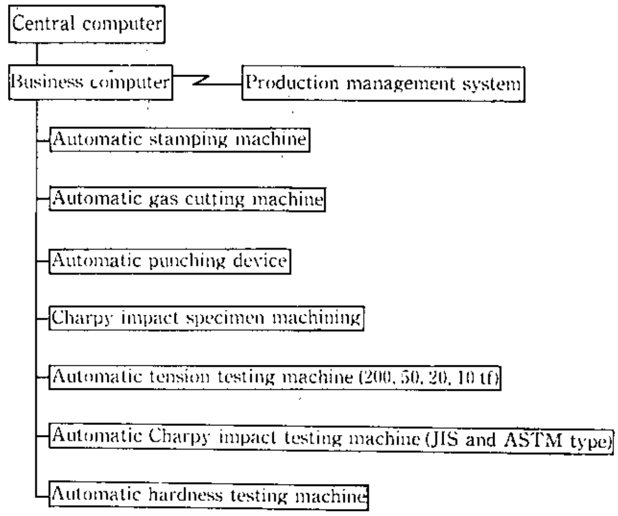


Fig. 2 System structure of mechanical testing process

Table 1 shows the automatic facilities and equipment recently introduced; **Fig. 2** shows schematically the flow of the mechanical testing process. At this Center, the an on-line business computer is linked to various automatic equipment, and machining, transfer of test information, and collection of actual records are automated.

3 Fully Automatic Gas Cutting[3)]

3.1 Total System

The fully atuomatic gas cutting machine is directly coupled to the plate mill shear line and controlled by the on-line computer. Except for the semi-automatic gas cutting of special steel materials, the entire system is automated. The physical layout of the system is show in **Fig. 3**; **Fig. 4** shows schematically the material flow. Sample plate cut at the plate mill shear line is transported to the Mechanical Testing Center by the table roller.

To prevent misidentification of materials, sample plate identification codes are read at the receiving station and re-input according to the actual order of receit. The sample plate is subjected to individual tracking, and stamping and cutting information are transferred to the automated equipment by the on-line computer and cutting is performed. Cut specimens are then sorted according to destinations. Spare samples are sent to an automated storage facility in line with actual cutting results, and inventory conditions are controlled.

Before cutting, the automatic stamping machine stamps a 10-digit identification mark at a position deter-

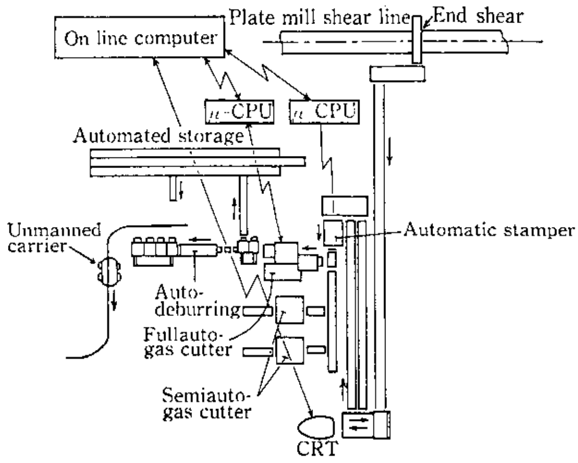


Fig. 3 Layout of gas cutting system

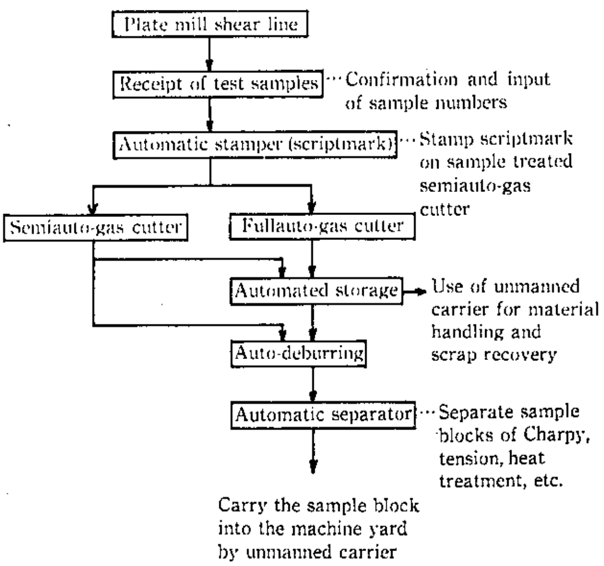


Fig. 4 Material flow of gas cutting system

mined by the cutting pattern. Sample plates with which the semiauto-cutting machine is used are given script marks.

After automatic gas cutting, specimens are turned face down, four-side deburring is performed by four deburring machines, and samples are automatically sorted into appropriate specimen bags. Spare samples are put into one of two types of spare sample bag, depending on whether the sampling was witnessed or not. When a bag is full, the operator checks for proper packing and transfers the bag to the location in the automated storage corresponding to the bag number.

3.2 Features of Equipment

3.2.1 Diversification of cutting patterns

This fully automatic gas cutting machine differs

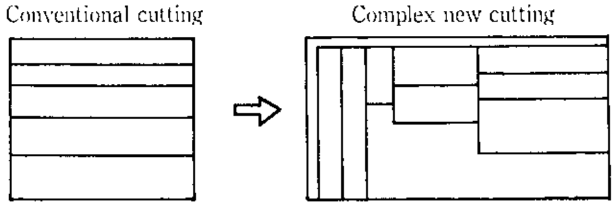


Fig. 5 Improvement of cutting pattern

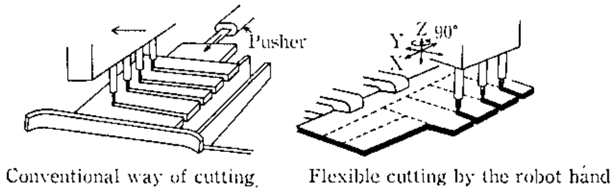


Fig. 6 Improvement of cutting method

from conventional machines in several respects. First, with conventional auto-gas cutting machines, simplification of the automatic equipment is achieved by widthwise cutting of a nearly square mother material, producing rectangular specimens, as shown in **Fig. 5**. The new device makes it possible to cut sample plates of various shapes in up to 50 complex patterns. This helps reduce sample plate yield loss, even though it makes the automated facility somewhat more complicated. Concretely, in the conventional method, as shown in **Fig. 6**, the mother material is clamped to the cutting table board to cope with the deformation due to thermal distortion which is likely to occur in the direction perpendicular to the cutting line with small cut specimens. The mother material is cut only at right angles to the board. In the present method, the mother sheet is hold suspended by the edge, as shown in Fig. 6. Cutting is performed by three torches. The torches are operated by an orthogonal robot with 4-axial degrees of freedom (X, Y, and Z axes and 90° rotation), and the torch intervals can be freely changed.

It was originally feared that thermal deformation would occur at the cutting line of small cut specimens in an upward direction and that the plate surface would warp downward. However, after a number of cutting tests, it was found that thermal deformation of narrow-width specimens presents no problem if the edge is cut away, and that downward warping of plate 4.5 mm in thickness is slight and causes no adverse effects. Thus the method was judged suitable for practical application.

3.2.2 Automation of handling of small cut specimen

Cut specimens were formerly pushed from the board, as shown in **Fig. 7** . In the new system, however, it is necessary to ensure that cut specimens are transported to the succeeding deburring process reverse side up. To satisfy this condition, a robot hand is used in

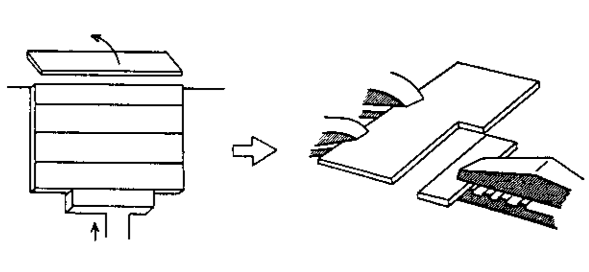


Fig. 7 Improvement of specimen handling

place of the conventional pusher, as shown in Fig. 7.

A structural drawing of the automatic gas cutting machine realized on the basis of the concepts in Sec. 3.2.1 and 3.2.2 above is shown in **Fig. 8**.

3.2.3 Automation of deburring

As a method of removing burrs, grinding is considered unsuited to automation, because over-grinding or partial grinding may occur, depending on the degree of burring. In the present method, therefore, cutting-off of the root portions of burrs using an air-vibrated chisel was adopted, achieving quick, reliable automated deburring.

3.2.4 Automation of special script mark stamping of semi-auto-cut material

Mother material which can be processed by the auto-gas cutter is automatically cut in accordance with cutting patterns stored in the cutter microcomputer, based on cutting information from the host computer. In this case, script marks are not applied.

On the other hand, script marks were formerly hand-written by slate pencil on materials whose plate thickness or shape made them unsuitable for processing by the automatic gas cutting machine. In the present method, the stamping machine is set to a stamping punch script-mark code; the stamping head moves along a pre-input marking pattern, achieving automatic marking. The stamping of identification codes on specimens has also been automated.

Major specifications of the fully automatic gas cutting machine are shown in **Table 2**.

Table 2 Specifications of automatic gas cutting machine

Size of sample plate	
Thickness	4.5~50 mm
Length	120~500 mm
Width	300~880 mm
*¹Strength	Less than 100 kgf/mm²
Weight	180 kg max.
Specifications of machine	
Gas	Propane gas
Number of torch	3
Fire nozzle	Nos. 2 and 3
Cutting robot	Rectangular robot*²
Handling robot	Rectangular robot*²
Working time	4.7*³ min/plate
Deburring	
Method	Air jet chisel
Cycle time	30 s/sheet

*¹ Restrictions imposed by stamping machine
*² Degree of freedom of motion: 4
*³ Case of standard cutting pattern

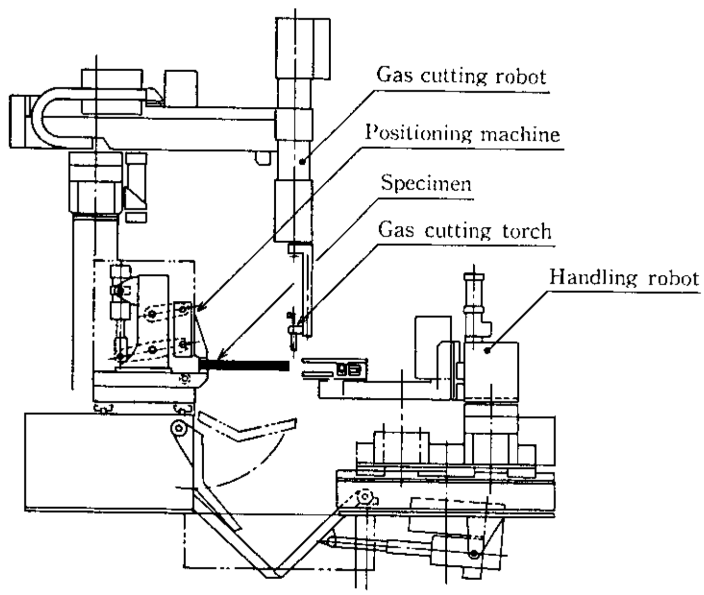


Fig. 8 Gas cutting robot

4 Automatic Device for Thin Sample Plate[4)]

When testing sheet samples, specimens such as those for tensile tests, Ericksen tests, and hardness tests are cut from the mother material. This procedure was formerly a bothersome manual operation performed with a shearing device, but for the present method, a punching device capable of producing a great many types of specimens under unmanned control was developed. The punching pattern is shown in **Fig. 9**.

4.1 Specifications and Construction of the Device

Major specifications of the automatic punching device for thin sample plate are shown in **Table 3**. This device consists of a punching device with punching dies of two clearance ranges, permitting punching of sample product thicknesses from 0.4 to 3.2 mm, and a transporting unit. The operator mounts a maximum 40 thin sample plates on the automatic punching unit shown in **Fig. 10**, inputs the identification numbers, and pushes the start button. Work instructions and punching information are then transmitted from the on-line computer, and a maximum of 19 specimens are punched from each sample plate under completely automatic control. The

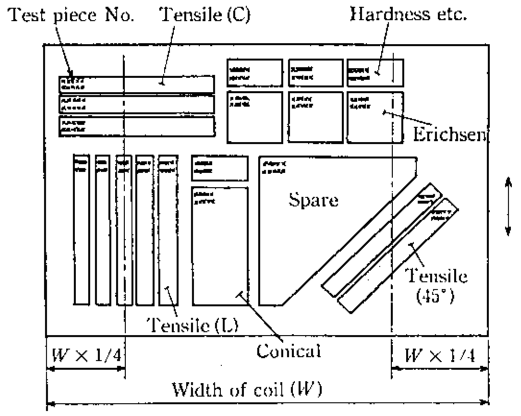


Fig. 9 Punching pattern for thin sample plate

Table 3 Specifications of automatic punching device

Specifications of device	
Number of turret station	72
Working time	4 min/plate (Standard punching pattern)
Stock of plates	Max. 40
Size of thin sample plate	
Thickness	0.4～2.0 mm
	2.0～3.2 mm
Length	600～1 600 mm
Width	500±50 and 750±20 mm

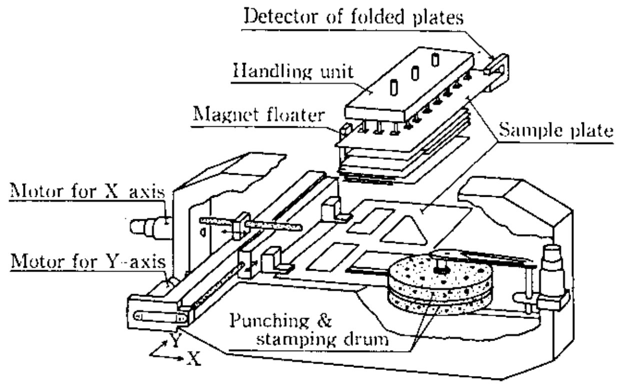


Fig. 10 Automatic punching device for thin sample plate

sample plates are lifted, one by one, by a vacuum pad, and grasped by a clamping unit, which automatically positions each piece in the X and Y directions. The selection of punching shape and the stamping punch are performed by rotation of a punching-and-stamping drum. The upper mold of the drum is fitted with punches and stamps, and the lower mold with corresponding rotary dies. Synchronization of the position of the clamp unit and the rotation of the punching-and-stamping drum permits automatic stamping and punching. The punching pattern is a set one, as shown in Fig. 9. The punching calculation is oriented to positions 1/4 of the plate width from the two sides and is performed by an NC unit. When punching is not required, punching information is left blank; thus only the necessary specimens are punched. Further, to minimize burrs due to punching, punch dies of two clearances are installed.

5 Automatic Charpy Impact Test Specimen Processing Machine[4)]

As a past example of an automated system of this type, one such system included four milling machines, a stamping machine, a milling machine for dividing, and a grinder, all arranged in series. The system, however, used too many milling machines and handling units, to be economically practical.

5.1 Specifications of the Machine

Major specifications of the new Charpy impact test specimen milling machine are shown in **Table 4**.

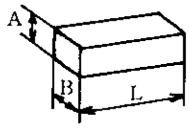
5.2 Features of the Machine

In the new device, the handling process has been simplified by placing an articulated handling robot at the center of the system machines. Further, the lengthwise center portion of a specimen is cut to necessary length, width, and thickness using a single milling machine. This is made possible by use of a clamping apparatus

Table 4 Specifications of Charpy impact test specimen machining

Specifications of machine	
Milling machine	Main power 11 kW
Dividing device	Main power 7.5 kW
Stamping machine	Alphabet and number of three figures
Deburring device	Belt sanding
Stock of blocks	Max. 40
Size of sample block	
Thickness	9～50 mm
Length	190±2 mm
Width	65 mm

Remarks: Size of Charpy impact test specimen



A: 10.3±0.1 and 7.8±0.1 mm
B: 10.3±0.1 mm
L: 55±0.1 mm

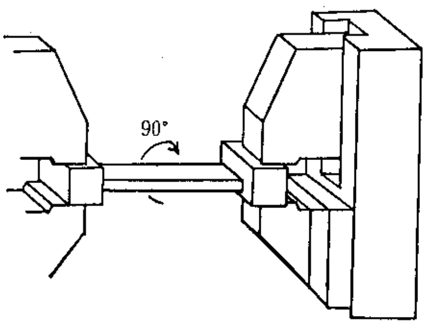


Fig. 11 Clamp and index device

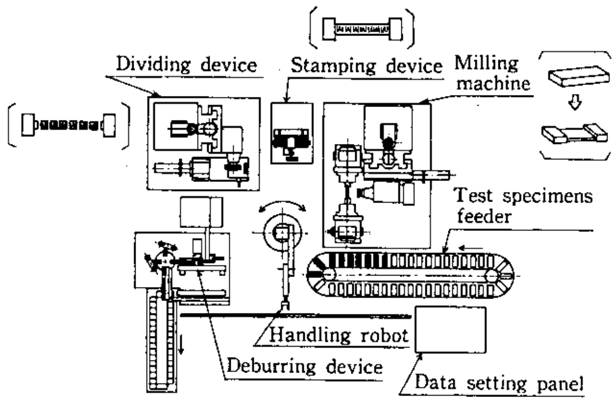


Fig. 12 Automatic machining process of Charpy impact test specimens

which rotates to 90° intervals, as shown in **Fig. 11**. Thus, the milling operation is quickly, and with high dimensional accuracy. In this way, the thickness of the specimen is reduced and its width narrowed only in the center portion in the lengthwise direction, and a 3-digit stamp is imprinted at the edge. Thus 3 to 6 specimens can be processed automatically. Since mass polishing of about 300 specimens, as in the past, is more efficient than individual polishing, polishing has been excluded from the automated system. As a result, the milling machine is very simple and low in cost. The layout of the automatic machining system is shown in **Fig. 12**.

6 Automation of Handling

The measures taken to minimize labor in handling specimens are outlined below.

6.1 Storage of Spare Materials in Multi-Tier Warehouse

As mentioned above, spare samples cut by the automatic gas cutting machine are automatically sorted depending on whether or not witnessing was required, and automatically stored in two respective bags. When a bag is full, the weight detector informs the operator, who checks for proper packing and gives destination instructions. The bags are automatically transferred to a multi-tier warehouse by a continuous-operation belt conveyor and stacker crane.

The bag number and shelf position number are made identical, and the bag number is recorded at the terminal of the on-line computer; thus spare materials are automatically inventory-controlled by the on-line computer in accordance with the actual results code from the time they are bagged. The maximum capacity of one bag is 500 kg, and on average about 400 bags are under storage at any given time.

6.2 Automatic Disposal of Spare Materials and Tested Specimens

Most spare materials are disposed of when testing is completed; this disposal operation requires great labor. In the present system, the on-line computer prepares a bag-by-bag disposal list. By simply indicating the bag number, the spare materials are transferred along the route—stacker crane → belt conveyor → automatic transfer car → disposal station. At the disposal station, the spare materials are automatically dumped into the scrap hopper. The empty bag is returned to its original address by the same route. Tested specimens are also automatically disposed of by automatic transfer car.

6.3 Automatic Transportation of Specimens

Cut specimens are automatically classified into four categories, Charpy, tensile, heat-treatment, and other tests, and transported to the processing station by automated transfer car. This car also returns empty bags, if any. Processed specimens are also automatically transported to the prescribed test room by operator-input destination instructions.

In sum, the transportation of main specimens is now automatic, and rarely requires human intervention.

7 Results

The advantages of the new system are discussed below in concrete terms; present operating ratios are shown in **Fig. 13**. First, to enhance the application ratio of the automated equipment, the processing pattern was standardized; as a result, the automatic processing ratio of the automatic punching device for thin sample plates increased to 81%. Except for experimental materials requiring special processing pattterns and specimens for which information is not available on the on-line computer, most processing has now been automated.

Major labor-saving effects of the new processing devices are as follows: In the fully automatic gas cutting system, the stamping, marking, cutting, deburring, and sorting operations were automated, reducing the number of operators from 18 to 8. With the automatic punching device for thin sample plates, staff was reduced from 6 to 3, while with the Charpy impact test specimen milling machine, three of six operators were eliminated. In short, processing personnel were reduced to about 1/2 and test personnel to about 1/3. The required testing time was also shortened, and the number of days required for the entire process from receiving through processing, testing, and acceptance-or-rejection judgment was shortened by 1.5 days for as-rolled steels and by 1.8 days for heat-treated specimens.

Further, automation of the processing and testing facilities has eliminated individual differences and human error, and the accuracy of processing and testing has both improved and stabilized.

8 Conclusions

The Mechanical Testing Center at Mizushima Works developed three new devices: a fully automatic gas cutting machine, an automatic punching device for thin sample plates, and a Charpy impact test specimen milling machine. These devices were developed to improve the efficiency of mechanical testing and automated handling. The results are given below.

(1) In the fully automatic gas cutting machine, the application of a robot to the cutting machine and provision of auto-script marking and auto-deburring made it possible to automate the entire process from punching through cutting, deburring, and sorting.

(2) The automatic punching device for thin sample plates employs the combination of a turret punching press, in which the punches and dies are embedded in disk, and transportation equipment, thus comprising a fully unattended system covering the entire process of material handling, marking, and stamping of various types of specimens.

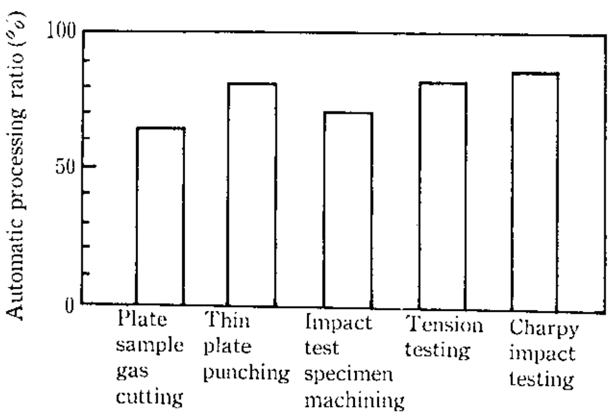


Fig. 13 Automatic processing ratio at the Mizushima Works Mechanical Testing Center

(3) For the Charpy impact test specimen milling machine, a processing system was developed in which the two ends of the specimen are clamped, making it possible to process all four faces at a single location without re-setting; a simplified and low-cost automatic processing facility was established by arranging the face-milling machine, stamping device, and split-milling machine around a handling robot.

(4) In the automation of handling, an organic integration of the multi-tier warehouse and automatic transfer cars realized an automatic transportation system in which the need for manned control of the storage and disposal of spare materials and the handling of specimens was virtually eliminated.

The Mechanical Testing Center is now operating smoothly and contributing to labor saving, process reduction, and the enhancement of the reliability of processing and testing.

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References

1) T. Shiraishi, I. Watanabe, M. Kameda, and H. Tanaka: *Kawasaki Steel Giho*, **16**(1984)1, 60-67
2) F. Ohnishi, M. Nakase, and S. Koishi: *Tetsu-to-Hagané*, **72**(1986)10, A336
3) A. Sato, S. Koishi, F. Ohnishi, K. Maegaki, Y. Fujiwara, and T. Sawada: *Tetsu-to-Hagané*, **72**(1986)10, A337
4) K. Maegaki, A. Sato, S. Koishi, T. Tsunekuni, T. Hirata, and H. Miyamoto: *Tetsu-to-Hagané*, **72**(1986)10, A338