Computerized Shot End and Die Locking Systems

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A die casting is a mechanically forced casting, having a gate speed as high as 3 m/sec or over, compared with 1 m/sec or less for other casting methods. Additionally, aluminum in mist is filled and pressurized in the cavity, which assures a constant supply of quality products in terms of the injecting conditions, die design, die coolant, and temperature control.

The injection mechanism has many control functions, and the best die conditions and offsets for maintaining the same injection conditions are the key to producing quality products.

Now the shot end master unit (SEMU), a modular injection control function of the existing die casting adaptive control system (DACS), has been developed by Toshiba and is being marketed internationally. Designed for general purposes, the SEMU is extendable and less expensive, and can be incorporated in the standard machines.

The present cold chamber type die casting machines tend toward high response and high speed, and are called upon to produce more complex, thinner-wall products.

For multi-speed injection, a constant aluminum charging amount is a must to control rise in the pressure. At present, the mechanical stopper-type injection valve is considered better to produce products of uniform quality.

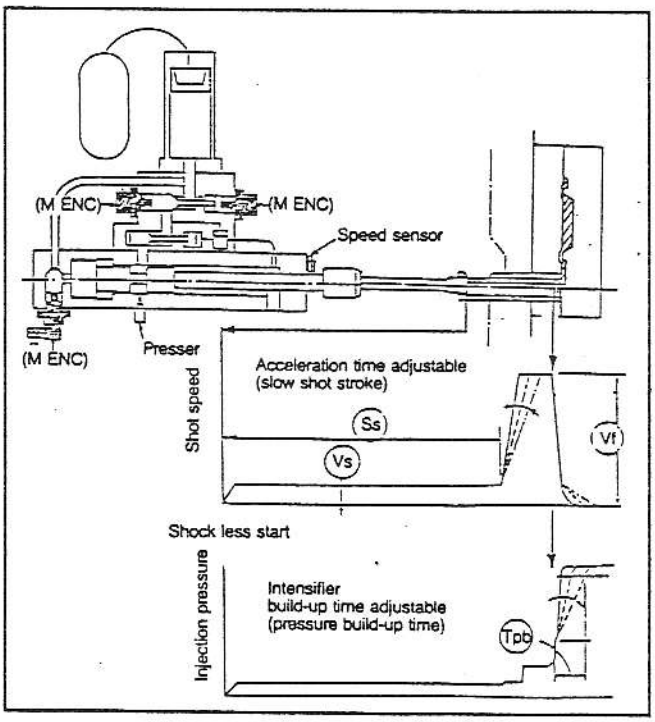

Fig. 1. Toshiba's new injection and sensing system.

Development and Control Method of SEMU

Toshiba has introduced a learning control technique to improve the injection capability of its die casting machines (Fig. 1). The injection capability is stabilized sufficiently with high repeatability, compared with conventional machines. To facilitate more stable and easier operation of the machines, the learning control was developed; the desired speed is preset by translating it into the open angle of the valve, and the open angle is compensated with the computed error.

Development of the computerized injection learning control started in 1981 (Fig. 2), and the prototype of the computer controlled die casting machine (CCD) was completed in 1982. With the upgraded control specifications, the DACS—a total control system for die casting machines—was born in 1984. Later, the SEMU made its debut with an improved injection control function of the DACS.

To understand the learning control technique, take the high injection speed control of die casting machines, for example. In actual casting operation, the high injection speed is lowered considerably by the gate resistance, compared with the cold shot speed. At the preview stage, inputting the cold shot speed characteristics and translation functions of the hot shot speed and valve-open angle must be performed on the computer.

The following translation functions are used for the SEMU.

$$R = f(\sqrt{P_{std}/P_{acc}} \times V_0)$$

$$V_0 = V_{sert} \times V_d/\sqrt{V_d^2 - V_{sert}^2}$$

$$V_d = f_2 \times (A_g/D_s^3) \times \sqrt{P_{acc}}$$

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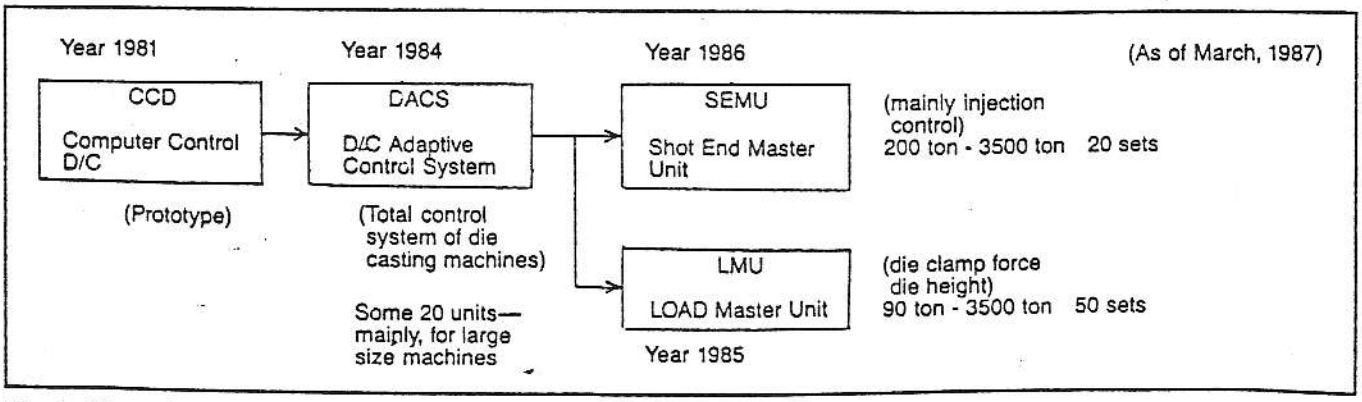


Fig. 2. Chronological development of Toshiba's computerized measuring system.

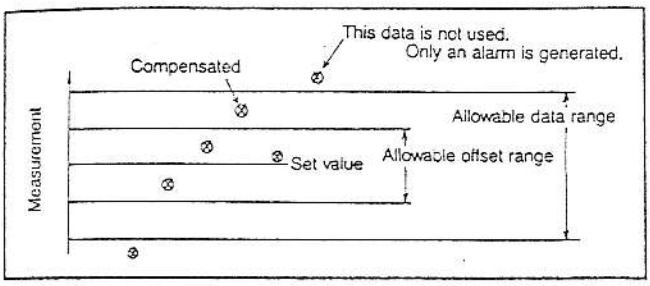


Fig. 3. SEMU's variable data sampling procedure.

R : Set open angle of valve
f( ) : Cold shot speed function
V_{set} : Set speed
f_2 : Flow rate factor
A_g : Gate cross section

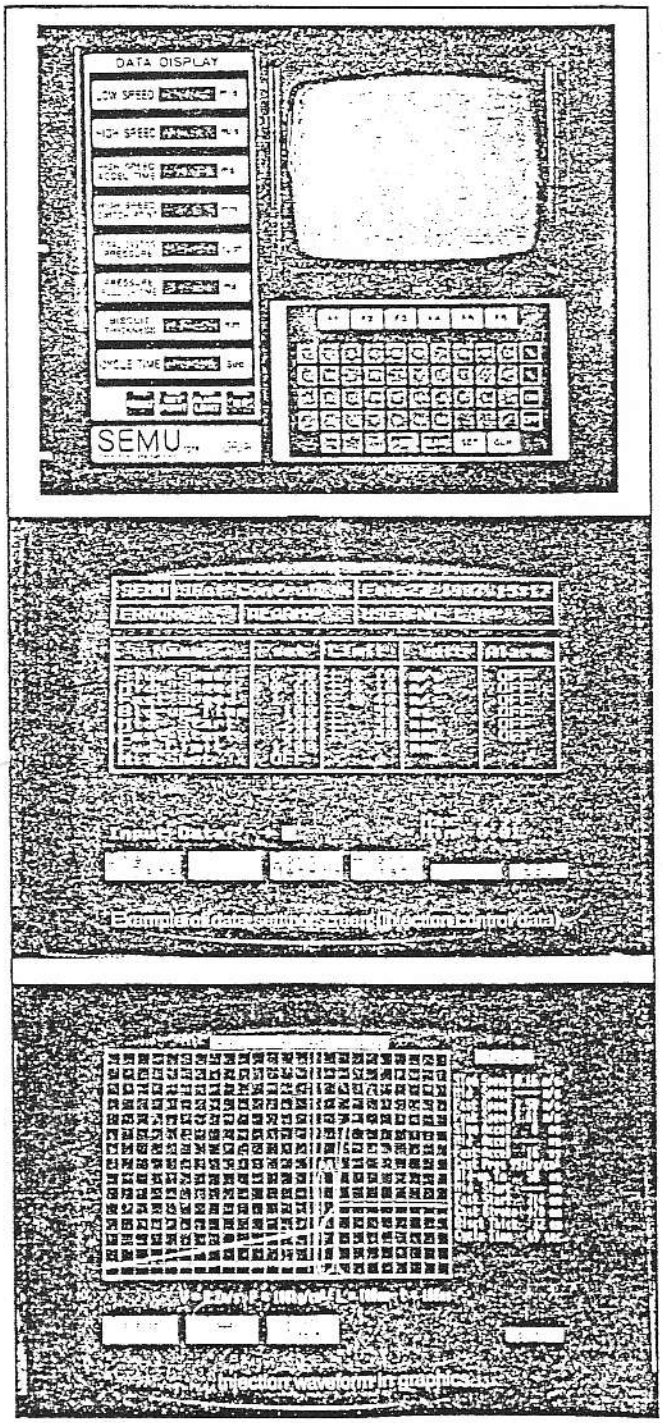


Fig. 4. Front view of SEMU panel and sample displays.

D_s : Sleeve diameter
P_{std} : Accumulator pressure at measuring of cold shot speed characteristics
P_{acc}: Present accumulator pressure

When actual injection starts—with the valve-open angle preset as obtained above—the actual measurement will be established. Then the parameter error is compensated with this measurement.

The parameter error factors cover the flow rate factor f_2, gate cross section A_g, and the like, but the flow rate factor f_2 is represented here as a major parameter error which is to be compensated.

The valve-open angle is computed again, using the compensated parameter, which is preset for the next shot.

Teaching the process of parameter compensation and preset is performed on the computer for review (Fig. 3). The learning control method may involve minor inconsistency in the measurements, caused by some external factors. Additionally, the measurements may differ widely, in emergency. To avoid such occasions—and to improve performance of the learning control—the company has tested extensively and has introduced three solutions into the SEMU:

Setting the allowances —Two allowances are established to signify the normal allowable inconsistency in measurements and allowable range to exclude the abnormality. Thus, over-offset caused by inconsistency in actual measurements and offset by abnormal value can be prevented.

Setting the number of data sampling—Another solution for preventing over-offset is to increase the amount of the data for offset and to use average value. Increasing the data sampling, however, reduces the response characteristics. To settle this problem, the SEMU (Fig 4) has variable sampling counts. The past operation references of Toshiba machines show that only one sampling count is enough to assure outstanding stability in the initial condition of the machines.

Asymptotic solution—This solution is used for parameter compensation with the predetermined ratio rather than for total offset. This concept is based on the normal feedback gain. Both fixed and variable ratio asymptotic solutions are available.

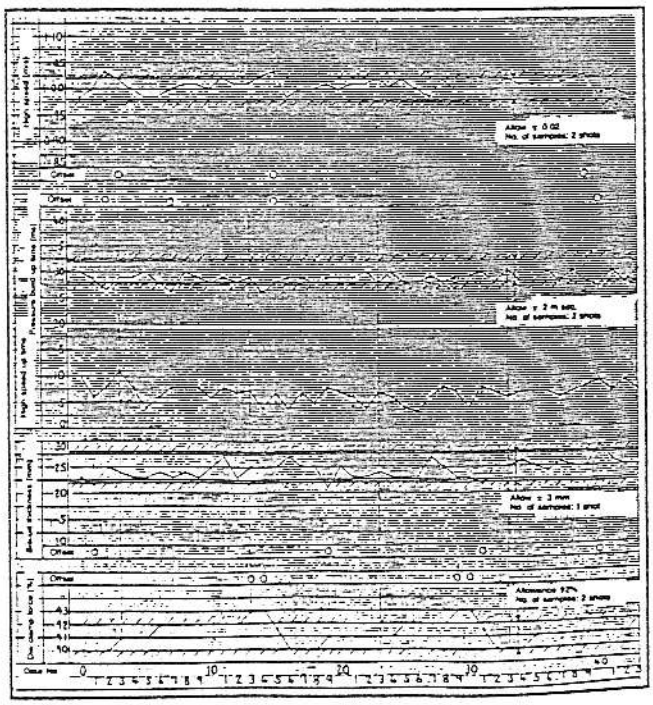


Fig. 5. Change under SEMU control (with offset function).

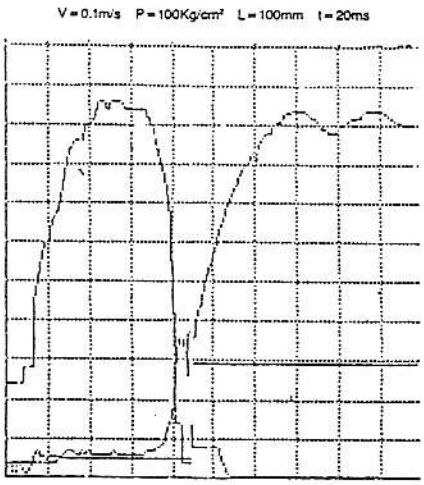
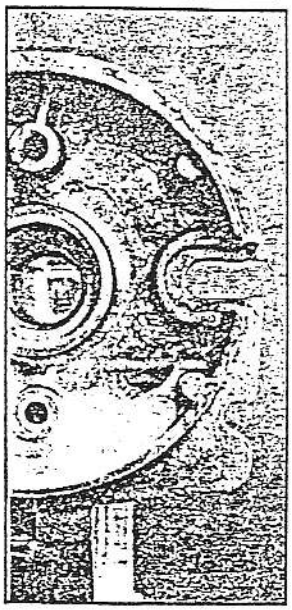
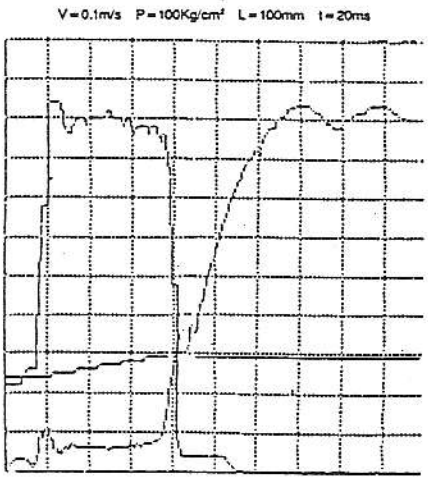
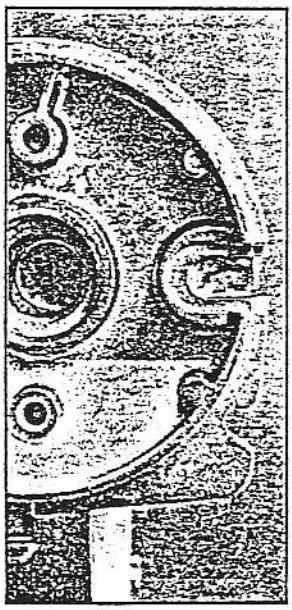
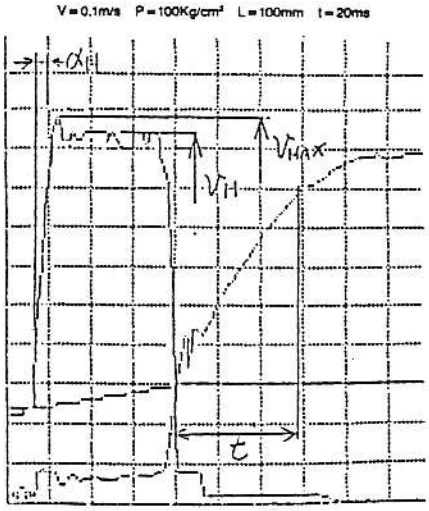
No.	Injection conditions				Analog data prints	Resultant casting
	High speed/Low speed (m/sec)	High speed accelerate time αH (m sec)	Pressure build-up time t (m sec)	Remarks		
1	0.97/0.24	16	30	Aluminum wrinkle Aluminum wrinkle caused by insufficient aluminum charging amount		
2	0.98/0.24	5	30	Generation of burr Open the high speed accelerate valve in the No. 1 condition. The product interior is burred.		
3	0.95/0.24	7	60	Accepted. Throttle the booster valve in the No. 2 condition.		

Fig. 6. Casting conditions, data printouts, and photos of portions of the resultant castings.

Table comparing Toshiba shot valve with electric flow control valve (double-circle is the top rating).

		TOSHIBA shot valve	Flow control valve (servo/digital valves)
Repeatability		◎ (Mechanical stopper type by means of check valve)	△ (Hydraulic pressure balance by means of spool valve)
Hysteresis		◎	○
Flow rate characteristics	High speed rise (0 2 m/sec.)	MAX ◎ (0.005 - 0.01 sec.)	MAX △ (0.025 - 0.06 sec.)
	2-step speed change	◎	○
	3-step speed change	◎	○
	Multi speed change	△	○
	Temp. drift (Open loop)	△	△
	Temp. drift (Close loop)	◎ SEMU	○
Pressure build-up characteristics (Control parameter)		◎ (Independent control by pressure detection)	△ (Speed control by position)

The SEMU introduces the learning study techniques as described above for the following seven items: low injection speed, mid injection speed, high injection speed, mid speed start position, high speed start position, pressure build-up time, and aluminum charging amount (for the Ladle-Master machine provided with aluminum charging amount controller).

The SEMU memorizes in the cassette the compensated parameters along with other setting conditions to assure the same injection conditions for the same dies. Thus, when the dies are used next time, the offset conditions for the dies—as well as setting conditions—are loaded from the cassette, and the same conditions are assured.

Function and Valuation of SEMU

Fig. 5 and 6 depict the change in pressure during the period from the start of the machine in the morning to 40-shot operation. Without offsets, the high speed increases gradually with the increase in number of shots.

The pressure build-up time is reduced sharply immediately after the machine is started, then reduced gradually with the increase in number of shots.

Equation for plunger motion (hot shot conditions):

$$V = \sqrt{\frac{As \cdot Pa}{\frac{r_0}{Ca^2 \cdot 2g} \cdot \frac{As^3}{Aa^3} + \frac{r_0}{CR^2 \cdot 2g} \cdot \frac{Ab^3}{AR^2} + \frac{rm}{Cg^2 \cdot 2g} \cdot \frac{AP^3}{Ag^2}}}$$

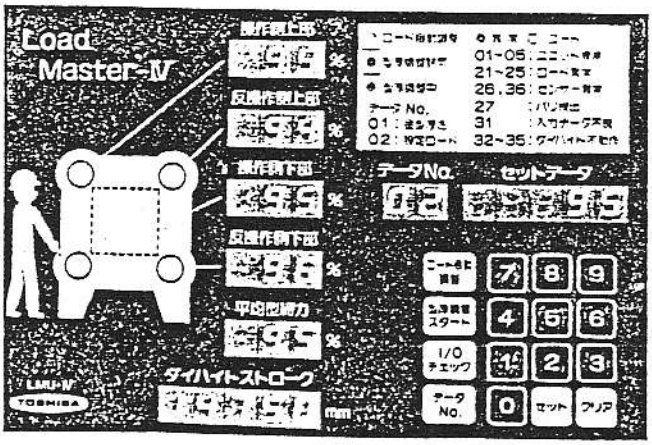


Fig. 7. Front panel of Load Master unit (Japanese version; photo of English-language panel not ready, yet).

where,

V: Speed (cm/s)
P: Pressure (kg/cm²)
A: Area (cm²)
C: Flow rate factor
r: Fluid specific weight (kg/cm³)
a: Accumulator part
S: Injection valve part
a: Piston head side
b: Piston rod side
R: Back pressure piping
g: Gate part
m: Metal (aluminum)

With an increase in the number of shots,

Pa ↗ (Rise in hydraulic oil temperature)
r_0 ↘ (Rise in hydraulic oil temperature)
Ag ↗ (Heat expansion)
— Vp increases.

Additionally, according to the following equation:

$$PV = m \cdot \frac{V^2}{2}$$

$$P = \frac{m}{V} \cdot \frac{V^2}{2} \qquad \text{where V: Volume (cm}^3\text{)}$$

$$= \frac{r}{g} \cdot \frac{V^2}{2}$$

with an increase in the number of shots,

V ↗
Δr ↘
— P increases to speed up the pressure build-up time.

As shown in Fig. 5, the number of offset is large immediately after the operation starts and reduces gradually thereafter. The SEMU allows the user to specify the desired allowances, number of samples, and offset factor according to the conditions for accepted products.

Other functions include the blanket loading of casting conditions (up to 60 different data can be stored in a bubble cassette), monitoring (display of waveform in graphics, in connection with the printer unit), and self-diagnosis (the alarm lamps flicker, with appropriate messages appearing on the CRT).

The die clamp load increases with the rise in die temperature. The die clamp load must be controlled to assure constant dimensions and geometry of the castings, protection of the machine and dies, and stability of the cycle.

The Load Master unit (Fig. 7) consists of the tie bar extension sensor, die height sensor, and indicators built in the controller. The absolute encoders are used for such sensors. All the operator has to do is specify the die clamp load and die thickness. Then the desired die height can be obtained, and the load is automatically offset.

Conclusion

It is well known that minor changes in the low speed or error in the narrow parallel lines can be discerned rather accurately with the human senses, but that changes in the high speed or pressure build-up time cannot be identified so easily.

To prepare this report, a sampling of approximately 3000 shots was carried out, where it was found out that although the absolute inconsistency for each shot was small, the high speed and pressure buildup time changed with the sleeve resistance and varying aluminum charging amount. Especially, changes occurred primarily in the initial 20 shots after restarting the machine, which had been stopped temporarily.

The SEMU plays a key role in stabilizing the filling and pressurizing of molten aluminum into the cavity, thus enhancing productivity.

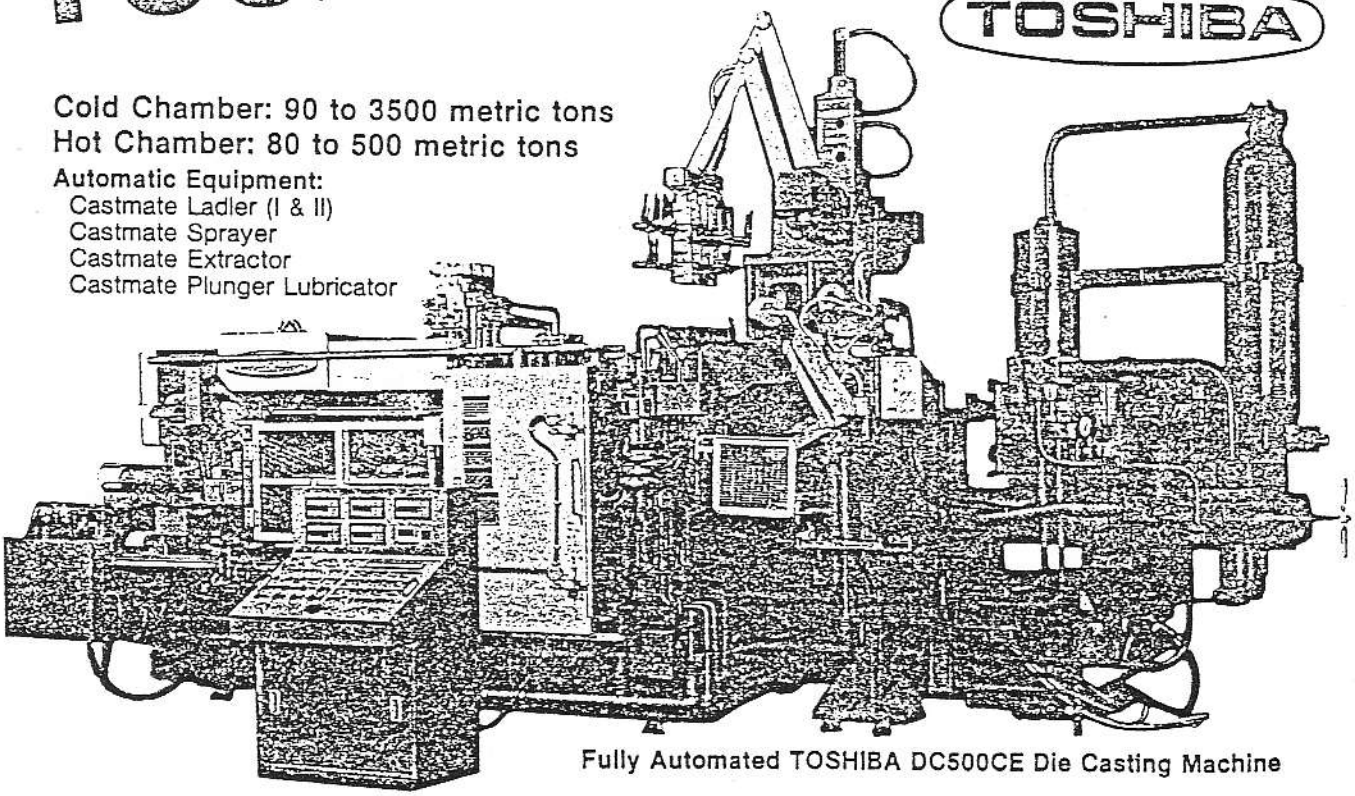
TOSHIBA Die Casting Machines can be profitable from the moment production starts: energy efficient, high quality castings and automation...**all you desire!**

TOSHIBA MACHINE

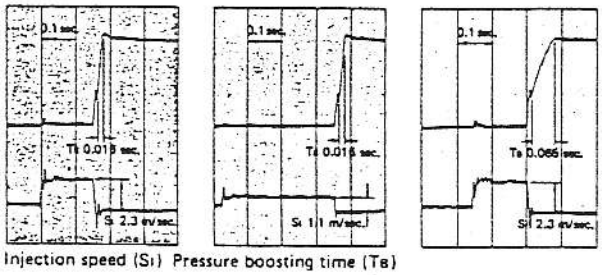
TOSHIBA

Cold Chamber: 90 to 3500 metric tons
Hot Chamber: 80 to 500 metric tons

Automatic Equipment:
- Castmate Ladler (I & II)
- Castmate Sprayer
- Castmate Extractor
- Castmate Plunger Lubricator

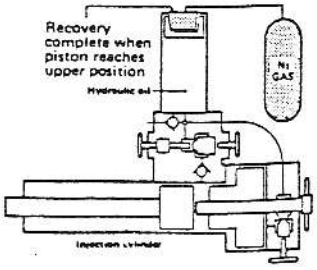


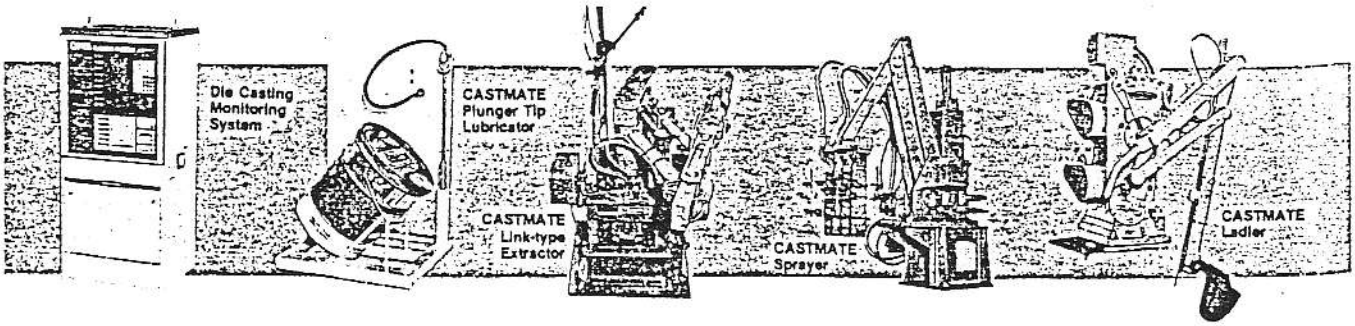
Fully Automated TOSHIBA DC500CE Die Casting Machine



Injection speed (Si) Pressure boosting time (Ts)

The **STANDARD** Toshiba shot end system features a surgeless hydraulic circuit, independent variable control for injection speed and intensification, and fast accumulator recovery.





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