Development & Application of the Acceleration-Based velocity measuring equipment for Elevators

Akira Tanakadate
Hitachi Building Systems Co., Ltd., Japan

Key Words: measuring, velocity, Acceleration, Correction

ABSTRACT

It is ruled to measure the elevator velocity periodically in order to monitor and maintain the performance of elevators. The conventional methods, which are done on the car or in the machine room, are not convenient and safe. We have developed Acceleration-Based Velocity Measuring Equipment, which can compute the velocity accurately through integrating the acceleration value detected by an accelerometer. With this device, anyone can measure elevator velocity in the car easily and safely, especially for machine-room-less elevators, by means of the non-contact method. We have applied it to improve the riding comfort adjustment method for hydraulic elevators.

1. INTRODUCTION

The current inspection standard sets forth that elevator velocity must be measured with a tachometer designed to take measurements in contact with a rail or rope.

Regarding this task, the conventional way to measure a hydraulic elevator is that a measurer gets on the elevator car, then the operator gives signals from with in the car and runs the elevator at high speed, And the service engineer presses the tachometer directly to the guide rail.

This technique was a direct method and had some room for improvement in safety. The author and his team have recently developed an acceleration-based velocity measuring equipment, which based on an accelerometer, jointly with Japan Aviation Electronics Industry, Ltd. The acceleration-based velocity measuring equipment is completely independent of the pulse encoder designed to control elevator velocity. The aim is to allow the service engineer to take the velocity measurements safely inside the car, without getting on it. The newly developed acceleration-based velocity measuring equipment thus allows anyone to measure the velocity of elevators easily and precisely.

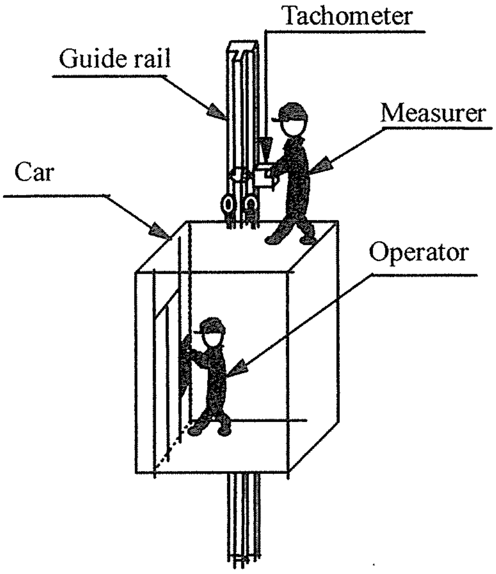


Fig. 1 Measuring velocity of hydraulic elevator

2. METHOD OF VELOCITY CALCULATION BASED ON AN ACCELEROMETER

2.1 Overview of the method of velocity calculation

The principle of acceleration-based velocity measuring equipment is to calculate elevator velocity by integrating the outputs of an accelerometer so placed as to detect the vertical direction. However, when the accelerometer input is set to "ao" and the accelerometer output is set to "a", the error component δa is included in the "a". That component therefore will also be integrated, resulting in the error increasing with time.

Here, let Vt be the real velocity and V be the velocity found through mathematical integrations. Then, we have

$$V = \int a dt = \int (ao + \delta a) dt = \int ao\, dt + \int \delta a\, dt = Vt + \int \delta a\, dt$$

$$[\int \delta a\, dt : \text{Velocity error}]$$

This error is characterized by the fact that it changes every second on the time axis and varies little by little with temperature as well. In conventional practice, service engineers were unable to remove the error effectively, thus being unable to obtain high-precision values.

A standard of velocity measurement inspection for elevators sets forth that service engineers should take readings near the intermediate floor with the highest speed achieved during the elevator travel from the bottom to the top floor.

To meet this requirement, acceleration-based velocity measuring equipment must have a measuring capacity of three minutes, which is needed as a maximum for most elevators to make one full run cycle. The target precision was set to ±0.5m/min or less, which satisfies a precision requirement equivalent to that of a tachometer currently used for obtaining integer readings. The author and his team then made it possible to obtain high precision values by performing corrections used to satisfy the target precision mentioned above. The following sections give an overview of these corrections.

2.2 Error reduction before measurement

The author and his team selected a servo accelerometer because of its high resolution, excellent phase characteristics in the range from DC to low frequency, and high resistance to vibration, humidity and other environmental conditions. Fig. 2 illustrates the principle of the servo accelerometer.

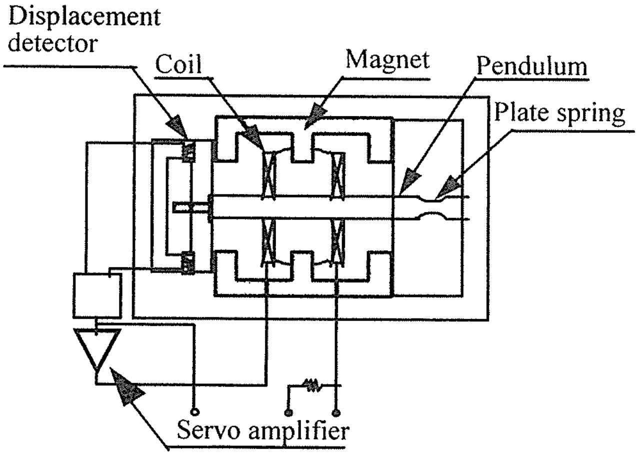


Fig. 2 Principle of servo accelerometer

This accelerometer consists of a pendulum supported by a plate spring and of a magnet, coil, displacement detector, and servo amplifier. Applying an accelerometer to the pendulum moves the pendulum away from the balance point, so that the displacement detector produces an imbalance signal, which the servo amplifier amplifies. At that time, the coil and magnet activates the pendulum so that the pendulum always goes back to the balance point. The current applied to the coil is then produced as an acceleration signal. Even this servo accelerometer, which the author and his team adopted, believing that it was the best, included some error in its outputs. After performing integrating operations for three minutes, the accelerometer accumulated its errors, thus being unable to achieve the target precision.

Regarding the reduction of output instability time due to the internal heat-up of the accelerometer after power-up, therefore, the author and his team put a thermistor inside the accelerometer and performed corrections for each measured temperature. As a result, as opposed to the ten minutes that it had taken for an output to stabilize in conventional practice, it now took only three minutes for an output to enter the stable region, thus indicating higher convenience. The author and his team also used a process of measuring a stationary state immediately before measurement, thus learning the trends in errors, and performing corrections on the assumption that subsequent measurements included errors entailing similar changes. These correction values are renewed for every measurement in the stationary state and are reset when one measurement comes to an end.

2.3 Corrections after measurement

It is true that the aforementioned action before measurement does reduce the error, but errors during measurement change at random, so that one cannot remove all the error. The velocity found through integrations thus includes an error, resulting in failure to meet the target precision. To determine velocity with high precision, therefore, required the author and his team to perform re-corrections according to the error after every measurement.

3. CORRECTIONS AFTER MEASUREMENT

In view of the error trends described in the preceding section, and to perform corrections in three minutes, which is the measurement time needed for the elevator to go and return (up or down), the author and his team paid attention to the stationary portion of the go-and-return travel of the elevator (that is, data at three points: before travel, intermediate stoppage, and after travel). These corrections are performed by determining a curve approximate to the error on the basis of the data in the stationary portion mentioned above where the velocity is clearly zero, and subtracting the error from the velocity calculation result. The reason why these corrections use the intermediate portion is that, if samples for error estimation are only before and after the measurement, the intermediate portion becomes more difficult to estimate as measurement time becomes longer, so that there occurs a difference between the estimated and the actual error curve.

In order to distribute the positions for taking samples of these measurements in an average manner, the author and his team used the intermediate stoppage portion between the rise and lowering, which is the only stoppage portion except for the times before and after travel.

Although the author and his team had established the method of correction mentioned above, it did not allow one to determine the intermediate stoppage point on the basis of the raw measurements. They therefore estimated the intermediate position on the basis of provisional corrections using the data before and after travel. The estimation is performed by the two steps: 1) determining as the center the midway point between the point where the car started to travel, exceeded ±3m/min, and then reached the range of no more than ±3m/min again on the basis of the provisional corrections shown in Fig. 3 and the point where it exceeded ±3m/min in the next travel, and 2) defining as the intermediate stoppage portion where the car satisfies an acceleration of $\pm 10 m/s^2$ or less during a total of 5 seconds, i.e., 2.5 seconds before and after the center mentioned above.

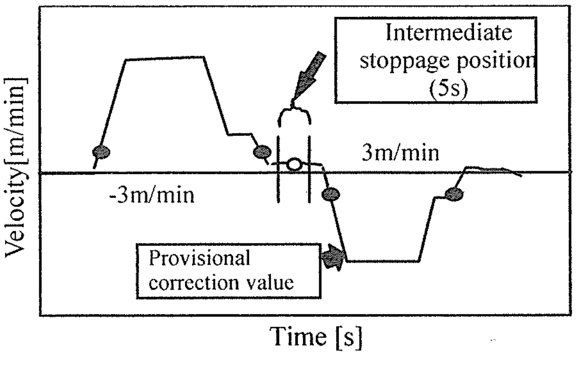


Fig. 3 Method of correction 1

The next step is to determine an error curve that passes through the raw data for stoppage portions in an equation of degree four at three portions shown in Fig. 4 and at the intermediate stoppage portion estimated in a pre-process, for 5 seconds before and after travel, and to subtract the error from the go-and-return velocity data, thus determining the desired velocity.

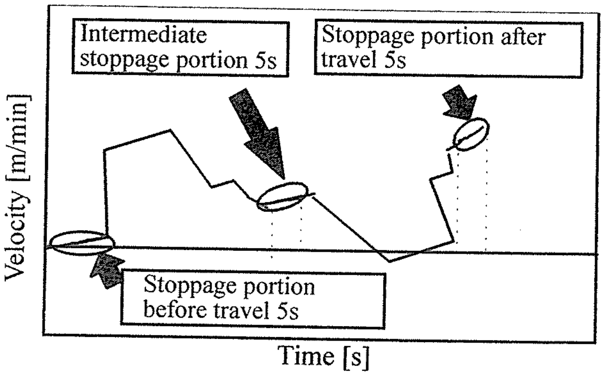


Fig. 4 Method of correction 2

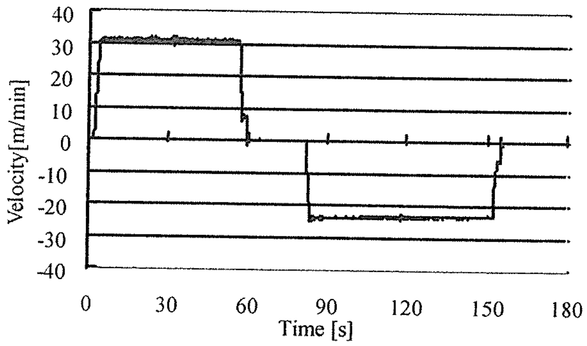


Fig. 5 Measurements of elevator velocity

Fig. 5 shows the measurements taken from the elevator on the fifth floor and Fig. 6 an enlargement of the portion near velocity zero, in order to assess the method of correction described in the preceding section. Fig. 5 demonstrates that upward and downward vibrations during travel exercise no influence and that the velocity error largely satisfies the target precision of 0.5m/min.

During the interval between 60 and 80 seconds, the car is still shows some noise-like vibrations, which are due to the opening and closing of the door.

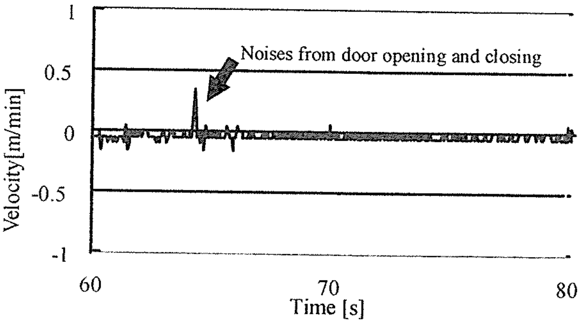
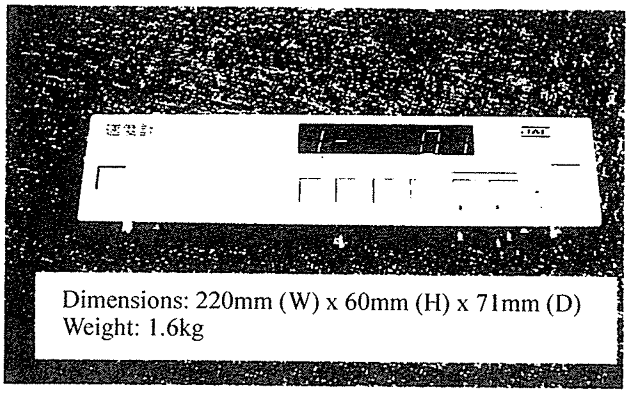


Fig. 6 Measurements of elevator velocity (enlarged)

4. OVERVIEW OF THE ACCELERATION-BASED VELOCITY MEASURING EQUIPMENT

Fig. 7 is an external view of the acceleration-based velocity measuring equipment that realizes the velocity calculation corrections whose reliability was proved in the preceding section, and Table 1 gives its specifications. Its main characteristics are as follows:

The acceleration-based velocity measuring equipment:
(1) Allows only one service engineer to take measurements safely. He has only to place the acceleration-based velocity measuring equipment on the car floor.
(2) Is lightweight, compact, and user-friendly. Unskilled operators can take measurements with it.
(3) Incorporates a rechargeable battery for use where no commercial power is available. (Once charged, the battery lasts for 2 hours.)
(4) Stores measurements.
(5) Measures car comfort performance (acceleration) at the same time.
(6) Communicates with ordinary personal computers. It assesses waveforms of vibration and velocity.



Dimensions: 220mm (W) x 60mm (H) x 71mm (D)
Weight: 1.6kg

Fig. 7 External view of the acceleration-based velocity measuring equipment

Table 1 Specifications of the acceleration-based velocity measuring equipment

Item	Specifications
Measuring range (display range)	Velocity: 0 to ±1666.0 m/min (0 to 999.9 m/min) Acceleration: 0 to ±1.96 m/s^2
Maximum measuring time	180 seconds maximum
Velocity precision	±0.5m/min or less (vertically only)
Acceleration precision	Input acceleration x ±2% or ±2 x 10^{-2}m/s^2, whichever the higher. (For the detection axis, choose either of the following: vertical, transverse, and longitudinal.)
Sampling	Velocity: 50 Hz, Acceleration: 200 Hz
Data output	RS232C digital output
Data memory capacity	Stores 5 measurements, 3 minutes each. (At power-off time, the backup battery retains the memory.)
Battery	Nickel-hydrogen accumulator
Battery operation time	Approx. 2 hrs (when fully recharged)
Battery recharge time	Approx. 3 hrs (when it is powered up after being attached to a battery charger)
Operating temperature range	0 to +40°C
Operating humidity range	95%RH or less

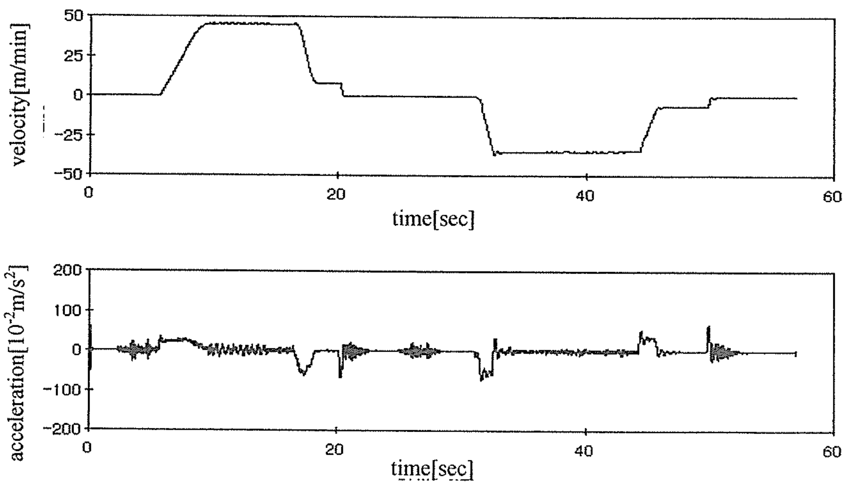


Fig. 8 Wave forms of velocity and acceleration

5. APPLICATION TECHNOLOGY FOR THE ACCELERATION-BASED VELOCITY MEASURING EQUIPMENT

Hitachi Building Systems uses this acceleration-based velocity measuring equipment to assess elevator comfort by transferring velocities and accelerations data measured by the acceleration-based velocity measuring equipment to a PC and displaying wave forms as illustrated in Fig. 8.

One example is a program that the company developed to automatically assess car comfort and adjustments made in the case of faults. The program is used to adjust the valve, which determines the comfort of the car of a hydraulic elevator, in an attempt to eliminate the need of technical skills in adjustment work, which used to be reserved for skilled personnel in conventional practice. As a continuation of these efforts, the author and his team will examine the possibility of using this acceleration-based velocity measuring equipment to examine the comfort quality and predict breakdowns in elevators.

6. CONCLUSION

This paper has presented an acceleration-based velocity measuring equipment that measures velocity safely, easily, and precisely. With this acceleration-based velocity measuring equipment, a service engineer can perform actual velocity measurement in the car. The author and his team therefore considers this acceleration-based velocity measuring equipment to be also effective in velocity measurements in low-overhead elevators with no machine room, which are expected to spread widely in the future.

This device also assesses waveforms of velocity and acceleration with a PC, so that it is widely applicable.

7. BIOGRAPHICAL DETAILS

Akira Tanakadate joined Hitachi Building Systems Co., Ltd. in 1993. He works for the Research and Development. His work includes the development of the maintenance tools.