



## THE LATEST TECHNOLOGY OF THE HEAVY PLATE LEVELLER<sup>1</sup>

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### Abstract

We have developed a new type plate leveller called 4th-generation in order to “Infinity Rigidity”. The new leveller will be able to maintain the work rolls at an ideal roll gap throughout the levelling work because any deflection caused by bending, compression of rolls, or longitudinal elongation of columns will be measured / calculated and immediately, dynamically compensated for by hydraulic cylinders.

By developing 4th generation leveler, we have achieved followings: Expansion of the leveling range : In case of X80(YS600MPa), From 20mm to 37mm; Improvement of flatness : 1 / 4 of flatness standard; Elimination of residual stress : Residual stress level 1 / 3 of former leveller.

**Key words:** Leveler; Heavy gauge; Plate; Flatness; Residual stress.

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## 1 INTRODUCTION

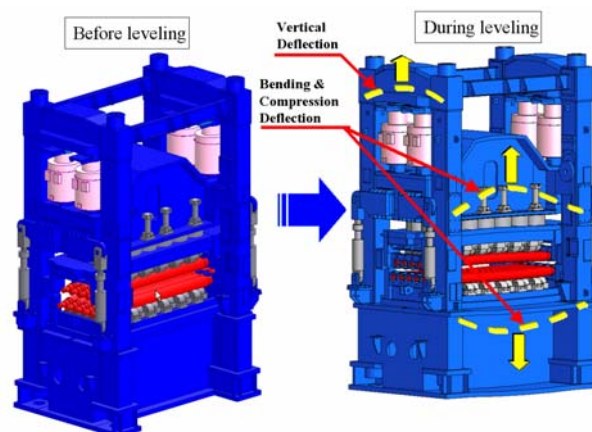
Due to a recent surge of requirements for flatness and reduction of residual stress and also due to a demand for improvement of productivity, innovative heavy gauge plate levellers (hereinafter referred to as the plate leveler or the leveler) have been developed.<sup>(1)</sup>

Our company has supplied as well plate levelers of our own development from 1965, and as the most advanced plate leveler, we have brought a plate leveler having a deflection correcting function of the 4th generation, which is called as dynamic crowning control system, into actual use in 1998. After that, we have established this deflection compensating technique and peripheral technology associated with the core technology through designing and supplying of 12 sets as of the end of 2010. In this paper, this 4th generation plate leveler technology and the peripheral technology having been established in association with it will be mainly presented.

## 2 ADVANCE OF DEFLECTION COMPENSATION

Although plate leveler in an early stage generally had a leveling force of approximately 20 MN (2040 tonf), in the case of leveling a plate with the load like this, such problems arose that a deflection was generated on the leveler itself, which caused problems of not being able to provide the heavy plate with a specified bend; the bending strength in the width direction became uneven; and so on, which resultantly caused a problem that the leveling capability was not made fully used.

In order to solve these problems, new deflection compensating functions have been added one after another. According to the advance of the deflection compensating function, plate levelers are classified in the 1st generation (a leveler having no deflection compensating function at all) to the 4th generation (a leveler having a latest deflection compensating function, and insuring to provide a bending strength all the time during leveling as initially specified).



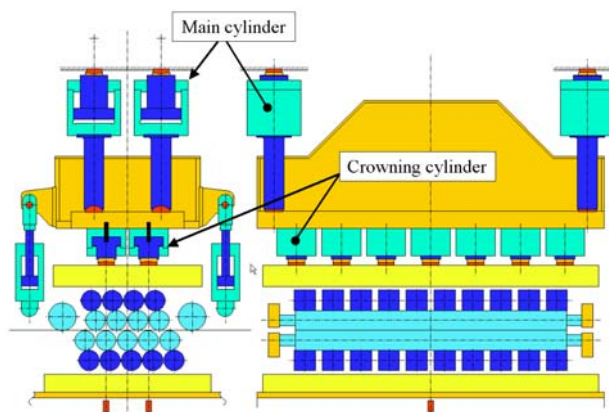
**Figure 1** Deflections before levelling and during levelling.

Figure 1 shows the deflections before levelling and during levelling a plate, and Table 1 is one in which a generation-by-generation summary of deflection compensating functions are listed.

**Table 1** Generation of plate leveller

Genera tion	Screw down	Bending system	Vertical Deformation Compensation	Lateral Deformation Compensation	Compression Deformation Compensation	Guarantee of roll gap	Year
1st	Worm & screw by motor	None	None	None	None	None	1960- 1975
2nd	Worm & screw by motor	Preset crown	None	Preset Compensation	None	None	1975- 1985
3rd	ARGC by Hydraulic screw down	Preset crown	Dynamic Compensation	Preset Compensation	None	None	1985- 1997
4th Intelligent type	ARGC by Hydraulic screw down	Dynamic crown	Dynamic Compensation	Dynamic Compensation	Dynamic Compensation	Yes	1998-

A plate leveller of the 4th generation has a capability of being able to keep a roll gap constant, even when the loads applied during levelling vary, as shown in Figure 2, by means of 4 hydraulic main cylinders having a function of setting the roll gap (a spacing between the upper and lower levelling rolls) and a dynamic function of compensating a vertical deflection (vertical extension of the housing), and further 14 crowning cylinders in total (2 rows in the travelling direction and 7 rows in the width direction of which are mounted on the upper frame or lower frame) having a dynamic function of compensating lateral deflections (bent deflections of the upper and lower frames) and compression deflections (compression deformations of the components such as levelling rolls, roll supports and so on).



**Figure 2** Heavy plate leveller of the 4th generation.

### 3 IMPROVEMENT OF LEVELING CAPACITY

A 4th generation leveller has a levelling effect which is improved by a large amount in comparison with a conventional 3rd generation leveller. This is greatly contributed by the fact that uniform and constant bending is applied with respect to the overall length and the overall width of a heavy gauge plate even when levelling force applied thereto vary during levelling. The following improvements in comparison to the pre 3rd generation leveller have been confirmed.

### 3.1 Improvement of Flatness

As compared to a former 3rd generation leveler, the flatness with respect to a heavy plate having a relatively large plate thickness or having a high strength, particularly with which the leveling force becomes large, is improved by a large amount. A result is obtained that the effect is large particularly with respect to a crossbow. With regard to materials in a range to which an appropriate bend is able to be given, including high tensile strength steel, the flatness equal to or less than one fourth (1/4) of the flatness prescribed in JIS standard (G3193), has been attained.

This is due to the fact that a method of preliminarily setting a deflection compensation amount on the basis of a load prediction (a presetting method) has been adopted until the 3rd generation, and when the predicted load did not match the actual leveling force, any leveling effect was not obtained, which often caused that the results of leveling varied. Moreover, the reliability on the 4th generation leveler's leveling effect of keeping a roll gap constant by changing the deflection compensation amount in correspondence to the variance of leveling force even in the case in which yield strength or temperatures vary in the rolling direction within one sheet of thick plate is significantly improving.

### 3.2 Improvement of Flatness of Top and Tail End

In the case of a former leveler of the pre 3rd generation, since a certain leveling force has been predicted in advance and a preliminary compensation of a bending deflection and a compression deflection has been carried out, the leveling force has greatly fallen below the predicted force and a uniform bend was refused to be given to the top end and tail end of a thick plate, which further varies to a large extent, so it was not possible to obtain a leveling effect, and moreover the flatness was even exacerbated in some cases. On the other hand, in the case of the 4th generation, since a deflection compensation matching load variances is carried out, uniform leveling of a bend is enabled and the leveling effect is obtained even at the portions of the top and tail end.

### 3.3 Improvement of the Effect of Reducing Residual Stress

It occasionally happens that, when a thick plate is cut into small pieces at an end user, the piece becomes deformed due to the influence of residual stress in the plate. This is seen particularly in the case of accelerated cooling plate or quench plate. Since such kinds of plate are increasing particularly in recent years, the case in which a complaint is brought by the customer is not a few. Also with regard to this residual stress, in a 4th generation leveler, residual stresses are significantly reduced as compared to the 3rd generation due to the effect of repeated uniform bending across the overall width and the overall length. The effect is greatly exerted on heavy plates used for shipbuilding and high tensile strength plates for construction machine.<sup>(2)</sup>

## 3 EXPANSION OF THE LEVELING RANGE

In a 4th generation leveler, since all the backup rolls are supported by 14 hydraulic crowning cylinders, these hydraulic cylinders serve as safety valves and

prevent leveling force to be locally concentrated. Therefore, it becomes possible to apply a further large load as compared to previous one, and thereby, it becomes possible to increase the leveling force. At present, a 4th generation leveler having the maximum leveling force of 100 MN (10,200 tonf) is available. This effect and the effect of the backup rolls having a high loading capability developed by our company jointly cause the prior maximum plate thickness to be increased to approximately 1.5 times. In addition, due to allowing the leveling rolls to be individually driven, it becomes possible to level a high tensile strength plate having an approximately doubled yield strength as compared to a conventional common driven type. Furthermore, also with regard to the minimum plate thickness, the biting limit is eliminated by adopting a special biting control and it becomes possible to straighten a high tensile strength plate having a thinner thickness as compared to a previous one. In Figure 4, a comparison of the leveling range with a 3rd generation leveler of our company is shown.

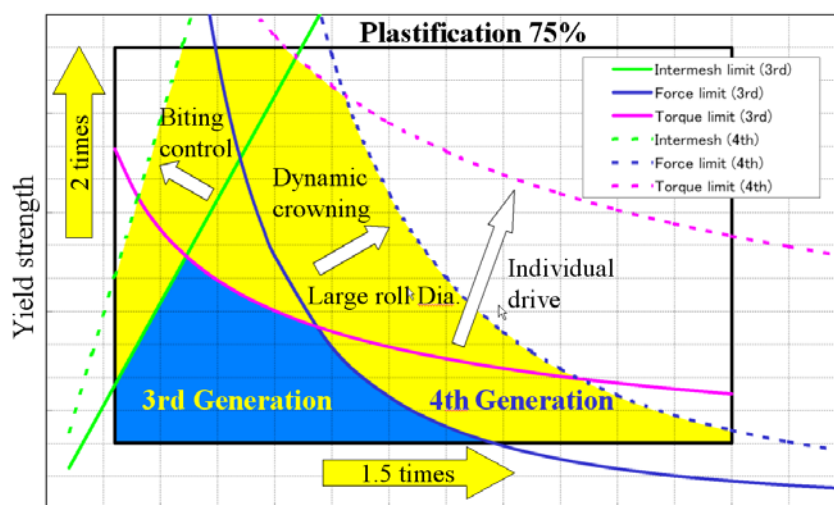


Figure 3 Comparison of the leveling range.

#### 4 IMPROVEMENT OF THE LEVELING CAPACITY DUE TO EMPLOYMENT OF AN INDIVIDUALLY DRIVEN TYPE

Since 2005, the levelers employing an individually driven method have rapidly become prevalent. It is effective particularly for leveling a high strength plate, which requires a large leveling power. In a prior commonly driven method using one motor, torque circulation, which is a phenomenon of causing a torque far exceeding the required leveling torque to be applied to the driving component, has occurred. In order to relieve the torque circulation, the number of drive motors has gradually been increased to two and then three, but even then, a torque equal to or more than double of the required torque has been generated. Since the individually driven method enables to completely remove the torque circulation, the leveling range has been able to be dramatically spread. A comparison of driven methods is shown in Figure 4.

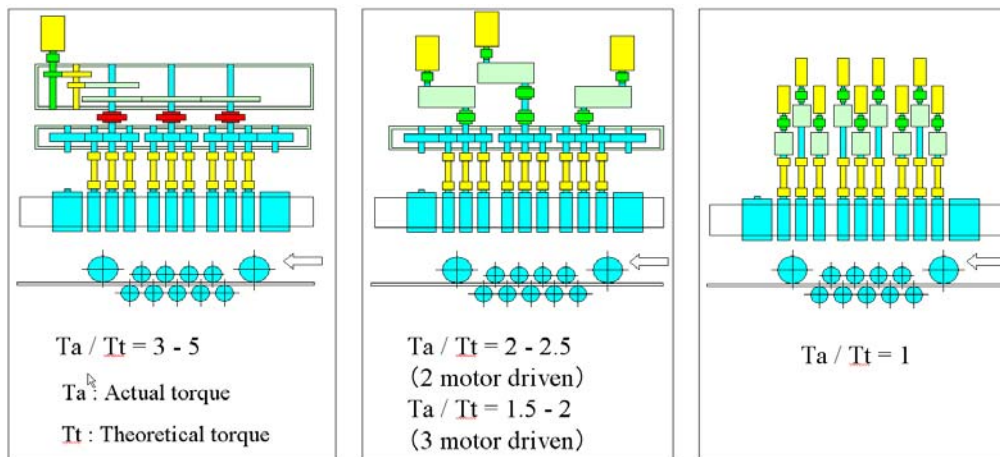


Figure 4 Comparison of driven methods.

## 5 IMPROVEMENT OF PRODUCTIVITY AND ON-LINE PLATE LEVELER

A 4th generation leveler has not only improved the effect of improving flatness to a great extent, but also greatly improved the reliability of leveling work. As the result, a substantial amount of the leveling work, which has required 3 passes or more with a prior leveler, becomes possible to be completed at one pass; therefore, it also becomes possible to level all plates by installing the 4th generation leveler not at an off-line site as before, but on a transportation table of the main line. (Hitherto, only the order of 5% to 30% of the total plates produced was conveyed to an off-line site to be leveled.) There is an example in which a 4th generation leveler is installed just after a cooling bed and all the thick plate products are leveled. In regard to a hot leveler, on-line leveling is already carried out even with the pre 3rd generation leveler at the present time, but this is due to that heavy plates in a softened state, being equal to or more than 600°C, are treated, and it is expected that a 4th generation leveler satisfactorily exerts its leveling effect in the case when a powerful accelerated cooling equipment or an on-line quenching equipment is installed.

## 6 LEVELING OF A PLATE WITH SCALE

In the case of leveling a plate having scales attached, it has happened that leveling rolls on the downstream side squeeze scales, which have been peeled off by leveling rolls on the upstream side, and causes an occurrence of a dent mark. In addition, it has also happened sometimes that peeled scales cumulate in mechanical equipment and cause the function of the mechanical equipment to reduce. Because of avoiding it, there is a leveler maker who is avoiding the problem by carrying out leveling work after removing scales from all plates, which are to be processed by a heavy plate leveler, beforehand at a shot blast facility. However, removing of scales of all the to-be-leveled materials in advance resulted in having an unnecessary process and was inefficient. Our company provides a 4th generation leveler having all the mechanical adjustment devices disposed above the surface on which a heavy plate passes through, for the sake of not having a problem when liberated scales fall, and also has developed and commercialized a scale blow device which discharges scales in between leveling rolls to the outside of the machine. By this, it has been actualized that straightening work can be carried out with a thick plate in a state of having scales attached thereon.



## 7 CONCLUSIONS

A 4th generation leveler was put into practical use in 1998, and technical improvements have been accumulated continuously after that, while the equipment has been supplied to many customers. The prior 3rd generation was called as "fuzzy" equipment, because the theory on a desk and actual operational data were not consistent with each other and therefore the result was not known until leveling was completed, and also the skill of an operator affected the result of leveling. Moreover, with respect to an identical to-be-leveled material, leveler makers have respectively determined various specifications. In the 4th generation leveler, however, since the roll gap during leveling becomes not to change, it has been progressed to link the theory with actual operational data, beginning with leveling force and power, and the reliability on the leveling effect has significantly improved. The 4th generation leveler, which has improved the flatness, leveling range, productivity and residual stress reduction effect, is becoming "a worldwide standard" as a cold leveler and a heat treatment leveler. Our company is intensively promoting technical development, and expects that the adoption as a hot leveler will increase by a large amount from now on.

## REFERENCES

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