Future Shinkansen rail renewal scheduled on the basis of passing tonnage will require much rail welding work. Rail welding work includes the actual rail welding along with grinding, and it currently requires considerable manpower because both are done manually. Welding a single rail takes as long as approx. 60 minutes, so only a limited number of rails can be welded in the limited track maintenance time. In the light of those, we developed a rail grinding machine for welds to improve grinding work efficiency. Using the developed machine, rough grinding of the rail top surface was completed in four minutes and manual finishing in 22 minutes. As a result, the whole welding process could be completed in 26 minutes, demonstrating that the machine could improve rail welding work efficiency.

**Keywords:** Rail welding, Rough grinding

1 Introduction

On-site welding of rails is currently mainly done through manual work by skilled engineers. Fig. 1 shows photos of current grinding work.

That rail welding work includes the actual rail welding along with rail grinding. Rail grinding is particularly hard, manual work using a stone grinder in a half-crouched position. It takes approx. 60 minutes to weld single rail, so second welding can be done only for three sets of rails a day within usual track maintenance time. Improvement of work efficiency thus has been demanded.

In the light of that, we decided to develop a rail grinding machine for welds for the purpose of easing the work and reducing the work time of rail grinding work.

2 Machines Developed in the Past and Their Issues

Various grinding machines for rail welding were developed in the past. One of those first measured the shape of the welded part of rails and grinded that part based on a grinding pattern input according to the measured shape. Another grinded rails by manual control to make the final rail surface irregularities less than the standard finishing values. Those only grinded the top surface and other parts of rails that could be easily machine grinded, and some manual grinding work remained. Fig. 2 shows one of the machines.

Those machines thus required that workers prepare heavy, complicated machinery in addition to conventional grinders and that the workers become experienced in their operation. In some cases, longer grinding time was also needed. Consequently, those are not used much in actual work.

We therefore aimed at developing a compact grinding machine for welds that would need no additional skill and would allow grinding in shorter time. Such a machine would need to take into account the division of roles between human and machine based on their respective advantages.
3 Development Details

3.1 Objective of the Development
Current manual grinding work includes rough grinding and finishing grinding. Rough grinding of excess weld metal on the foot, web and head of rails takes approx. 20 minutes, and finishing grinding of surface irregularities of a rail approx. 40 minutes per meter of rail.

We decided to develop a machine for rough grinding work that involves a large amount of grinding and demands much labor, not accuracy. The part of rails to be ground is the rail top surface only because the foot and web of rails are currently ground by hand in a short enough time and those parts have shapes too complicated to be machine-ground. Finishing grinding was left manual with a stone grinder, as finishing work requires fine human skill, however some finishing work was mechanized. The developed machine can grind excess weld metal as much as possible without affecting preset distortion and longitudinal fine finishing of rails. Fig. 3 shows the comparison of the rail grinding work before and after the development (gas pressure welding).

3.2 Grinding Methods
Rail grinding methods (abrasives used) are classified into three major types. Table 1 lists the features of each of them.

<table>
<thead>
<tr>
<th>Grinder tip</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grind stone (current)</td>
<td>- Grinding according to worksite possible - Grinding possible at high temperature</td>
<td>- Low grinding efficiency - Short replacement cycle</td>
</tr>
<tr>
<td>Milling cutter tip</td>
<td>- High-efficiency grinding possible - Grinding possible at high temperature</td>
<td>- Low grinding accuracy</td>
</tr>
<tr>
<td>Belt</td>
<td>- Highly accurate grinding possible</td>
<td>- Low grinding efficiency - Grinding difficult at high temperature</td>
</tr>
</tbody>
</table>

All three methods have both advantages and disadvantages. The features needed for rough grinding are to be applicable even at high temperature just after welding and to be able to efficiently grind in a short time. Comparing those three types, we concluded that the disadvantage of low grinding accuracy of the method using a milling cutter tip could be improved to a certain acceptable level by reducing grinding speed and minimizing the amount of grinding without affecting manual finishing with a stone grinder later on. We thus decided to adopt that method with low grinding accuracy but high grinding efficiency. Fig. 4 shows the milling cutter tip to be used.

3.3 Machine Operation
In order to make a compact machine that needs no additional skill and grinds an appropriate amount at acceptable accuracy, we designed the following grinding method with a simple automatic control mechanism.

(1) The grinding unit automatically measures the difference between the height of the welded rail top surface and the adjacent original rail top surface (height of the excess weld metal) on its own based on electric current value (load value).

(2) Taking into account the amount of rail distortion, the machine automatically calculates and controls the grinding amount to maintain height of excess weld metal at 0.1 mm or more, preventing excess grinding of rail base metal.

(3) Considering grinding accuracy of the method, prevention of too much grinding, vibration on the machine body, and smoothness of the rail surface after rough grinding, we set the grinding pitch at 0.2 mm.

(4) For efficient machine operation, we set appropriate stroke according to the amount of rail distortion.

Fig. 5 shows the basic machine operation based on the above-mentioned considerations.
3.4 Downsizing of the Machine Body

For on-site use, we designed the machine body to be as compact as possible. As the amount of rail surface irregularity per meter is evaluated after grinding, we specified a grinding amount where excess weld metal would be maintained at more than 0.5 mm after grinding based on consideration of the amount of rail distortion, subsidence of the welded part by cooling, and later manual finishing. We therefore set the lateral movement stroke at 300 mm, with the center at the excess weld metal to be grinded, so as to downsize the machine body. Fig. 6 shows the setting of the lateral move stroke, and Fig. 7 shows the developed grinding machine for welds.

![Fig. 6 Setting of the Lateral Move Stroke](image)

4 Verification Tests

4.1 Testing Method

Assuming second welding work as the type of rail welding performed, we selected gas pressure welding. The testing method was as follows.

1. Weld two 1.2 m long rails with gas pressure welding.
2. Grind the welded part using the developed grinding machine for welds.
3. Manually finish using a stone grinder.
4. Check the finished rail surface after grinding using a 1 m rail top surface measuring device.

We checked performance of the machine by measuring the time needed for (2) and (3) and the smoothness of the rail surface after grinding. Fig. 8 is a photo of grinding with the developed grinding machine for welds, Fig. 9 a photo of the rail surface after rough grinding with the machine, and Fig. 10 a photo of manual finishing work.

![Fig. 7 Developed Grinding Machine for Welds](image)

1. Detects height of welded rail top surface with grinding unit.
2. Detects height of adjacent original rail top surface and calculates height to be grinded.
3. Lowers to 0.2 mm below welded rail top surface and starts grinding while moving laterally.
4. Grinds welded part while moving to turn-back point. At turn-back point, comes down a further 0.2 mm and restarts grinding in reverse direction.
5. Repeats step 4 until reaching height detected in step 2.
6. After reaching height detected in step 2, stops drive (grinder) motor, moves to center, and ends operation.

![Fig. 5 Operation of the Grinding Machine for Welds](image)

![Fig. 8 Grinding with Developed Grinding Machine for Welds](image)
4.2 Test Results

Table 2 shows the verification test results.

<table>
<thead>
<tr>
<th>Measurement value</th>
<th>Rail surface irregularity per meter (mm)</th>
<th>Avg. grinding time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vertical irregularity</td>
<td>Alignment</td>
</tr>
<tr>
<td>Ave.</td>
<td>0.0</td>
<td>0.3</td>
</tr>
</tbody>
</table>

- Automatic rough grinding of the excess weld metal using the machine could be completed in within five minutes each of seven times.
- Manual finishing with a stone grinder after rough grinding with the machine could be completed within 25 minutes each time.
- The machine could easily be set immediately after welding. We found no damage to the milling cutter tip after the final test.

Fig. 11 is the vertical irregularity chart, and Fig. 12 is the alignment chart.

5 Conclusion

- By adopting a grinding method using a milling cutter tip, we could improve grinding efficiency and complete grinding in a short time.
- We could confirm that automatic grinding enabled anyone to operate the machine in almost the same grinding time.
- Designing a mechanism to measure and control the height of the excess weld metal allowed automatic rough grinding with better accuracy than ever before. As a result, time required for manual finishing using a stone grinder after automatic rough grinding also could be reduced.
- Setting the lateral move stroke at 300 mm allowed grinding in shorter span and in shorter time, reducing total work time required.

6 Issues for the Future

We could reduce grinding time by grinding excess weld metal using the developed grinding machine for welds. But, the machine grinds only the rail top surface, so rough grinding of the rail head side surface still has to be done manually. As we were able to reduce grinding time of the rail top surface using the machine that could grind the excess weld metal as much as possible without affecting fine finishing, improvement of the machine to enable grinding of the rail head side surface would achieve further reduction of total grinding time and higher work efficiency.

Reference: