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Rail Grinding for the 21st Century – Taking a Lead from the Aerospace Industry

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ABSTRACT

Rail grinding is a key maintenance activity for Network Rail. It is performed at night through possession of the track so process speed is critical. Increasing the metal removal rate (MRR) of the rail grinding operations would be a way to improve this. The aerospace industry has seen advances in grinding technologies recently that have increased MRR. This work was aimed at assessing their best practice and its application to rail grinding operations.

Current Network Rail grinding operations include preventative and corrective re-profiling of the rail head. The majority of work performed in the UK is preventative re-profiling with current train speeds ranging from 1-10mph. Opportunities exist to increase train speed and improve the productivity of this operation through the use of more advanced grinding technologies.

The most relevant aerospace technology is High Efficiency Deep Grinding (HEDG). This uses high wheel surface speeds, superabrasive tooling and high workpiece feed rates to remove material quickly from the cut-zone. Productivity improvements were identified by applying theory on power requirements (by assessing Specific Grinding Energy) and chip thickness of the grinding process. Computer CAD/CAM modelling was also performed to assess the effect of changing grinding techniques on potential gouging of the track infrastructure and/or interference with example trackside obstructions.

The work concluded that opportunities do exist to improve the current productivity of grinding operations. Utilising HEDG technology theoretically provides a 100% train speed increase (utilising the same power available with the current set-up) for preventative re-profiling. This requires the application of high grinding wheel surface speeds and superabrasive technology. Further increases in train speed require increased spindle power. The chip thickness experienced by grinding grains is reduced for a peripheral grinding setup and high wheel surface speeds which is beneficial for wheel wear. The application of HEDG technology cutting on the periphery of the wheel provided optimum conditions during CAD/CAM simulation to avoid rail gouging, and any potential collision of the grinding stone with modelled track side obstructions.

Keywords: rail grinding; superabrasive; HEDG technology

1 INTRODUCTION

Rail grinding has been identified by Network Rail as a key maintenance activity [1]. The majority of maintenance work is performed at night through possession of the track which has significant impact on the network capacity. Network operators are constantly looking for process improvements in rail grinding in order to provide a cost benefit for these activities and reduce track possession time. These benefits ideally include increasing the life of grinding wheels, commonly referred to as stones in the rail sector, which would allow increased grinding time during shifts before the time consuming task of replacing the stone; and increased train speeds which could lead to a reduction in the overall amount of time required for maintenance.

Currently Aluminium Oxide (AlOx) is used as the abrasive in grinding stones. A typical tooling setup utilized is shown in Figure 1 (from [2]), where the stone interacts with the track under a constant force, face grinding process. In order to gain benefits for the network operators, stone manufacturers make tweaks to their AlOx designs to improve performance and life, but these are subtle and only provide small improvements for the maintenance operations. Work has been carried out to study effects of different grinding techniques on, for example, rolling contact fatigue [3] or derailments [4], but nothing is evident in the literature in terms of investigating the possibility of making a step change in grinding technology that provides a significant impact on the productivity, and subsequently cost, for the network maintenance operations.

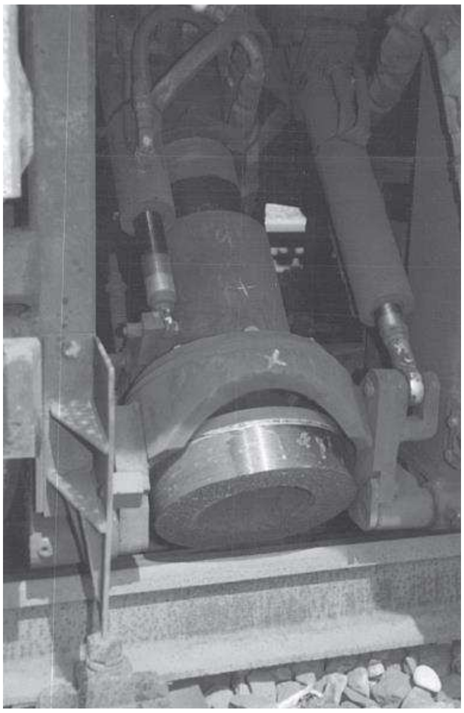


Figure 1. A Grinding Module showing a Typical Grinding Stone in a Face Grinding Set-up (from [2])

It is proposed by the authors that an increase in the metal removal rate (MRR) capability of the grinding operations would provide a significant opportunity to impact on the current constraints detailed above by translating into faster train speeds, for operator defined depths of cut, leading to a reduction in maintenance times. Industry sectors such as aerospace have seen significant advances in grinding technologies recently, resulting in increases in MRR. There is wide spread use of “superabrasives” such as cubic boron nitride (CBN), and other techniques, which have led to significant increases in both wheel life and MRR in comparison to the conventional abrasives such as Aluminium Oxide.

This paper outlines a comparative modelling study of key grinding parameters which are utilized to identify potential improvements that could be made to the current rail grinding operations using best practice techniques from the aerospace sector. The parameters of Specific Grinding Energy and Chip Thickness, which are both directly related to train speed, were modelled using the current Network Rail process and varying aerospace grinding techniques to identify potential improvements in productivity. Further CAD/CAM simulation modelling was included to investigate the potential implications of practically applying alternative grinding methods in a rail grinding environment.

2 CURRENT RAIL GRINDING PRACTICE

Current Network Rail grinding operations include preventative and corrective re-profiling of the rail head. The majority of work performed in the UK is preventative in order to re-profile the track and remove small defects with small depths of cut, typically less than 0.5mm. This is performed on both straight track and curved sections. Corrective re-profiling is performed on sections of heavily worn/plastically deformed track and/or defective rail. Its primary purpose is to re-profile the track to its original form and is usually performed on shorter sections of track with larger depths of cut. The different operations will be identified as preventative or corrective where appropriate in this paper.

Both these operations are currently done at varying rates with train speeds ranging from 1-10mph. Opportunities exist to increase train speed, for both preventative and corrective operations, and depth of cut, where appropriate for corrective work, to improve productivity of these operations through the use of more advanced grinding technologies. Although the current depths of cut for preventative re-profiling are determined by the material removal required from the rail head and not the grinding process; an increased capability for larger cut depths per grinding stone would facilitate minimizing the stone requirements per train that could also lead to cost savings. As the largest potential benefit for Network Rail exists in improving their preventative re-profiling operations, all modelling performed in this paper is for the preventative rail grinding process with the primary focus concerned with an increase of train speed for this operation.

New technologies have been introduced into the industry including milling and planing processes that show good potential for achieving large cut depths particularly relevant to corrective re-profiling operations. These were assessed in the recent INNOTRACK project and guidelines for their use issued [5]. However, the majority of UK re-profiling requirements are preventative operations on longer sections of track which would greatly benefit from increased train speeds. Developments have been made here as well with the introduction of the “high speed” grinding technique involving “non-driven” stones that removes a very shallow depth of cut [6]. Although a significant step forward, this is better suited to networks with long sections of tangent track which are found in the primary user’s country, Germany. The UK infrastructure is more complicated with a significant amount of curved sections, and varying cut depth requirements depending upon track usage. Driven stones are still required to accommodate these different conditions and this work aims to investigate best practice techniques from the aerospace industry that best fits the UK’s needs for these operations. The possibility of using peripheral grinding (i.e. using the outer edge of the stone) rather than face grinding has the potential to offer additional benefits and was also investigated.

3 BEST PRACTICE IN AEROSPACE GRINDING

The requirements for high productivity and accuracy for the machining of components in the aerospace industry has led to significant advancements in grinding technology. A number of different grinding techniques developed for, but not exclusively used in this sector, were evaluated to assess their applicability for rail grinding operations. These are detailed as follows:

Creep Feed Grinding – Creep Feed Grinding (CFG) was a concept introduced in the 1960's which extended grinding from a surface finishing operation into a stock removal process. The process is very different to conventional surface grinding and is characterised by a large depth of cut applied at a slower work piece feed rate. The benefits of the process include a low force per grinding grit, which provides low force for a given area of cut meaning large depths of material can be removed in one cutting pass. However, friction is high producing high contact zone temperatures and high energy requirements in the process. The large contact zone allows slow thermal dissipation therefore reducing potential damage to the surface, but typically a large amount of cutting fluid is applied to transfer the heat away from the cut zone.

Continuous Dressing – A dressing process in grinding is a method of preparing the cutting profile and adjusting the cutting grain sharpness to provide optimum cutting conditions. A process of continuous dressing (CD) was applied to CFG when problems with wheel clogging and loss of profile were limiting productivity. Wheel loading refers to the build-up of material in the voids on the grinding wheel surface. These voids are purposefully included and function as pores into which the machined chip can initially enter while still within the arc of contact. Subsequently these chips are then jettisoned from the wheel due to the centrifugal force and applied coolant. Should these pores become clogged, wheel loading is said to occur. In this case, machined chips are smeared and bonded to the surface of the grinding wheel reducing its ability to cut effectively; resulting in an increase in cutting force and temperature and ultimately leading to catastrophic failure. Dressing is normally performed by applying harder abrasive material, e.g. diamond, to a rotating grinding wheel to remove the top surface exposing fresh cutting grains. The benefits for this type of process include: increased consistency of cutting conditions; controlled wheel wear and maintenance of wheel profile geometry. In addition, it has been shown that the application of CD during grinding can reduce the specific grinding energy by a factor of 4 during cutting [7].

VIPER Grinding – VIPER grinding is a concept developed and patented by Rolls-Royce PLC. It uses CFG with an improved coolant application technique. Coolant is applied as a jet with high flow rate and pressure at a position on the grinding wheel just before the cut zone. This has the effect of cleaning the wheel preventing wheel clogging, and allowing coolant to penetrate into the grinding wheel providing increased lubrication and cooling.

VIPER grinding offers increased performance in productivity through its cleaning and cooling capability allowing larger MRR without damaging the work piece material. To implement this requires the application of coolant just before the cut zone at 70bar pressure and a flow rate of approximately 100l/min. It is understood for a rail grinding setup that all coolant products would end up on track and have to be in conformance with environmental standards. It would be possible to meet this requirement, but of course the coolant still has to be carried on the train.

High Speed Grinding

High Speed Grinding (HSG) is defined by Tawakoli [7] as grinding wheel surface speeds exceeding 60 – 80m/s. This is the common definition for HSG and is different to the patented train technology described in [6] in section 2. The exact value of required wheel surface speed to achieve HSG is not defined but the majority of traditional grinding processes operate up to 50m/s. As a result, HSG is classed as any operation where wheel surface speed exceeds the above. The main advantage of HSG is that higher wheel speeds reduce the size of the metal chip each abrasive grain produces during cutting. This allows for higher productivity through increased work piece feed rates whilst maintaining a chip size that the grinding wheel can accommodate. In general, increasing the wheel speed is beneficial to any grinding process. The main technical issues occur with the tooling. At high wheel speeds, the wheels must be rotated at high rpm. This can result in wheels bursting. Steel core wheels, as shown in Figure 2, are required to avoid this.

Figure 2. Steel Core Plated Grinding Wheel

HEDG Grinding

High Efficiency Deep Grinding (HEDG) is a novel abrasive machining process which readily achieves very high material removal rates. The technique is a development of CFG and HSG. By combining a high depth of cut, work piece and wheel surface speeds, the cutting conditions and hence the thermal behaviour of the process are fundamentally changed. These changes in thermal behaviour result in high temperatures in the wheel–work piece contact zone (contact layer), which facilitates material removal. However, due to the high work piece speed the heat is removed with the grinding chip before significant penetration into the work piece surface is allowed to occur [8]. It was decided that this would be the most suitable technology to explore for a potential rail grinding performance increase, and from this point onwards all modelling work was focused on this technology. This selection was made as HEDG technology has the greatest potential to deliver increased grinding train speeds via an increase in the material removal rate, and the primary focus of this work is the improvement of preventative re-profiling operations. Additionally, it was also felt that as it is imperative to avoid a heat affected zone on the rail head, and HEDG was the only process that combined high productivity, with minimisation of work piece heating.

4 GRINDING PROCESS ASSESSMENT

This section outlines the main parameters (specific grinding energy and chip thickness) that are commonly used to characterise the grinding process. Using these parameters, improvements in the rail grinding process can be identified.

4.1 Specific Grinding Energy

Grinding is a complicated process to characterise as a grinding wheel has a large number of undefined cutting edges. As a result, the majority of parameters utilized in grinding consider the process from a macro perspective which allows comparisons between different types of grinding. The concept of Specific Grinding Energy (SGE), e_c, is a simple method of evaluating different grinding processes. It is the amount of energy required to remove a unit volume of material:

$$e_c = \frac{P_{Net}}{Q'_w.b} = \frac{P_{Net}}{a_e.v_w.b} \quad (1)$$

where P_{Net} is the net power and is measured at the spindle, Q'_w the volumetric removal rate per unit width of the grinding wheel (i.e. the productivity of the process) and calculated from process parameters (a_e, depth of cut and v_w, work piece speed), and b the width of the grinding wheel. The units are J/mm^3. Lower values of e_c indicate a more efficient grinding process with an increase in the amount of cutting by the abrasive grain as opposed to rubbing and friction effects. The more efficient a process is, the more material that can be removed for the same energy consumption. Equation (1) represents a ratio of measured values. The net power output is not fixed; a change in any one variable relating to productivity will cause a change in the power output measured and the subsequent calculation of SGE. Specific grinding energy is very dependent on productivity. Research performed on HEDG grinding shows that the SGE reduces as Q'_w increases [7, 8]. Figure 3 shows that the SGE tends towards a minimum value with an increase in productivity following a power law curve. This indicates that the process become more efficient at higher productivities, as the rate of net power increase is less in comparison to the increase in productivity. The lowest values measured for SGE in literature are around 10J/mm^3 [7, 8] and would always remain above zero. The current rail grinding process, for both preventative and corrective re-profiling, has productivity values that can take advantage of this effect.

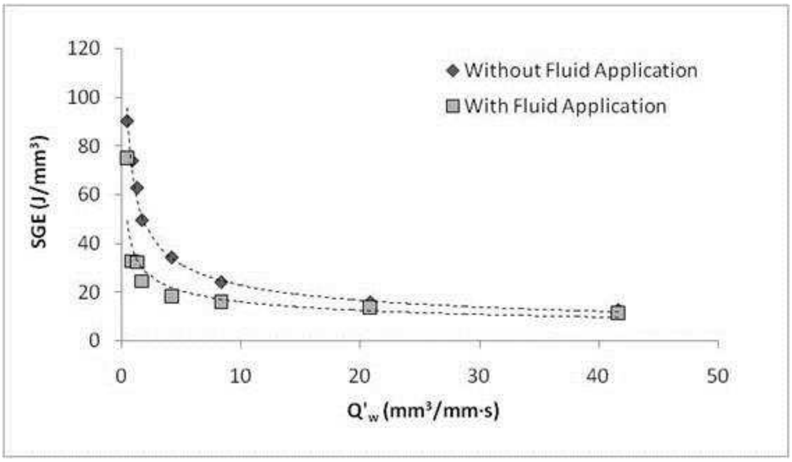


Figure 3. Specific Grinding Energy versus Productivity for HEDG grinding of Steel (from [8])

4.2 Chip Thickness

The second important parameter to understand when characterising a grinding process is the chip thickness, h_m. This is an approximation of the size of material that is being cut by an individual grinding wheel grit. This is important because if a grinding chip is too large, it will fill the pore between cutting edges and the wheel will become clogged. This can lead to large amounts of rubbing, friction and subsequent thermal damage. Commonly used equations for peripheral and face grinding undeformed chip thickness are shown in Equations (2) and (3) respectively [9].

Peripheral grinding: $$h_m = \left[\frac{4}{Cr} \left(\frac{v_w}{v_s} \right) \left(\frac{a_e}{d_e} \right)^{\frac{1}{2}} \right]^{\frac{1}{2}} \qquad (2)$$

Face grinding: $$h_m = \left[\frac{\sqrt{3}}{Cr} \left(\frac{v_w}{v_s} \right) \right]^{\frac{1}{2}} \qquad (3)$$

where v_w is the grinding wheel speed, v_s is cutting tool speed, a_e is the depth of cut, d_e is the grinding stone/wheel diameter, C is the number of active cutting edges per unit area of grinding wheel surface, and r is the ratio of the width to the depth of the triangular chip cross section. Additionally, Figure 4 is included to highlight the concept of chip thickness with respect to peripheral grinding.

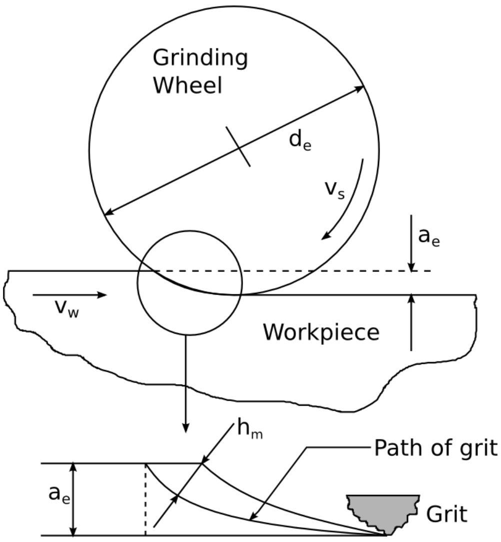


Figure 4. Schematic representation of the concept of Chip Thickness as applied to Peripheral Grinding (adapted from [9])

5 POTENTIAL GRINDING IMPROVEMENTS

The parameters detailed in Section 4 provide the basis for potential improvements in the current rail grinding process. More productivity is possible for the same power input if the specific grinding energy of a process is reduced. However, the chip thickness must also be considered, as if an increased productivity is achieved at the expense of an increase in this parameter, the pores on the grinding wheel may become quickly blocked. The current rail grinding process for preventative re-profiling operations is defined in Table 1. The parameters represent face grinding using Aluminium Oxide, fibre reinforced resin bonded wheels. The width of cut, b, is estimated from an approximate cut distance of 75mm, over the rail head, divided by the number of grinding stones per rail on the Loram C21 series train utilized for the majority of preventative work by Network Rail, 32 in total. It is understood that different facet widths are encountered by different stones on the grinding train and the vertical force applied changed to achieve the desired depth of cut. However a set value for facet width has been selected for this modelling application in order to highlight the potential performance increase for a different grinding setup using the method detailed above.

The values in Table 1 are estimated from the current Network Rail face grinding process information. The C21 series of rail grinder use 30hp spindles and the net power, used for cutting, is approximated at 80% of total power utilized. An assumption is also made that the trains are operating near full power with the current process. To investigate a performance increase, the specific grinding energy of other industry processes must be considered. Research performed on the grinding of steel using a HEDG style process [8], indicates that specific grinding energies of $10J/mm^3$ can be achieved in dry grinding. Assuming the successful application of the HEDG process with a minimum specific grinding energy of $10J/mm^3$, then we can estimate for the same process the theoretical train speed parameters. Table 2 shows the potential train speed increase when applying a peripheral HEDG process.

The second consideration when calculating a new theoretical train speed is the value of chip thickness as defined in equations (2) and (3). Table 3 details the relevant chip thickness and wheel grit sizes required to deal with increased train speeds. Constants C and r were calculated from information provided by Tyrolit [10] on a typical Aluminium Oxide grinding wheel. A mid value of 35m/s for the current wheel surface speed was chosen for the example calculations. This calculation is performed in order to benchmark the current process before any potential improvements are considered. The chip calculations show that as the train speed increases, the size of the chip experienced by the individual grinding grain also increases in value. As a result the size of the abrasive grits on the grinding wheel must increase to provide large enough voids for the chip to exit the cut zone. It is approximated that a grinding grit protrudes from a wheel bond by 50% of its diameter creating the void for chip formation to occur. This approximation governs the grit size detailed in Table 3.

High train speeds can result in a high value of grinding chip thickness if the speed of the wheel/stone is not increased. A theoretical train speed of 20mph starts to create a very large theoretical chip when face grinding as shown in Table 3. Using larger grit stones to overcome this can create the additional problem of increased surface roughness. Switching to a peripheral grinding process significantly reduces the chip size according to Equations (2) and (3) and also provides more overlap between passing grains leading to reduced values of surface roughness on the finished surface. Increasing the grinding wheel surface speed also reduces the chip size which opens up the potential for increased productivity by retaining a reasonable size grinding chip. Large chip sizes can lead to increased wheel wear so it is important to consider both the power requirements and chip size for a grinding process.

6 SIMULATION OF GRINDING TECHNIQUES

Section 5 highlights the potential improvement in the grinding process by altering from a face grinding operation, where significant rubbing occurs, to grinding using the periphery of the grinding wheel. However, it is important to establish the impact of this change on the grinding kinematics and whether this interferes with track geometry or any potential obstructions that may be present around the rail. Simulation of rail grinding cut paths using the different grinding setups was performed using the CAD/CAM program Pro-Engineer. The main aim of the simulation was to assess the effect of changing grinding techniques on potential gouging of the track infrastructure and/or interference with example trackside obstructions.

Table 1. Specific Grinding Energy for Current Preventative Re-Profiling Face Grinding Process

Grinding Type	a_e (mm)	b (mm)	P_{Net} (HP/kW)	v_w (mph)	e_c (J/mm^3)
Straight	0.1	2 – 3	24/17.6	10	13 – 20
Curved	0.2	2 – 3	24/17.6	5	13 – 20

Table 2. Potential Train Speed for Peripheral HEDG Grinding Process for Preventative Re-Profiling

Grinding Type	a_e (mm)	b (mm)	P_{Net} (HP/kW)	v_w (mph)	e_c (J/mm^3)
Straight	0.1	2 – 3	24/17.6	13 – 20	10
Curved	0.2	2 – 3	24/17.6	6.5 – 10	10

Table 3. Chip Thickness Values for Current Preventative Re-Profiling Face Grinding Process

Train Speed, v_w (mph)	V_s (m/s)	a_e (mm)	d_e (inch)	Peripheral h_m (μm)	Face h_m (μm)	Approx Grit Size Required (μm)
10 (current straight track face grinding)	51	0.1	11	-	225	450 (based on Face grinding process)
20 (straight track face grinding increased train speed)	51	0.1	11	-	318	650 (based on Face grinding process)
20 (straight track face grinding increased train & wheel speed)	150	0.1	11	-	186	375 (based on Face grinding process)
20 (peripheral straight track increased train speed)	51	0.1	11	67	-	150 (based on Peripheral grinding process)
20 (peripheral HEDG process)	150	0.1	11	38	-	100 (based on Peripheral grinding process)

6.1 Simulation Set-up and Methodology

As detailed above, the current Network Rail grinding process incorporates three main operations; preventative re-profiling on straight and curved track, and corrective re-profiling. The CAD/CAM model set-up was created to incorporate these varying operations into one simulation model to test the different grinding setups. Whilst the model was capable of considering corrective re-profiling grinding, this is dependent on the deviation of a given rail profile from the required condition, and is in such case specific. Therefore, the results shown are for preventative grinding operations on straight and curved track, where a nominal 0.1mm of material is removed around the rail profile. Two models were overlaid including the final cut geometry and the excess stock model to create the CAD/CAM test piece geometry detailed in Figure 5.

The rail cross section was modelled directly from the European Standards 56E1 [11] using Pro-Engineer. This was chosen as the representative track geometry to run the comparative simulation scenarios. This model is useful to understand the potential of using CAD modelling to test various tooling setups, but extra work would be required to fully represent a grinding train application. The model length was limited to a 10m straight section with an additional 5m curved section which a 100m curve radius representing the tightest curvature any grinding stone would interact with during curved preventative re-profiling. The CAD/CAM model was limited to the dimensions listed in order to avoid a large CAD model size which would reduce the computational cost efficiency of the simulation. In addition to the track, a typical track side obstacle representing rail-mounted equipment, i.e. potential obstructions for the wheel/stone, were included based on information provided by Network Rail for an Axle Counter. The model provided the baseline test piece for all the simulations performed and the grinding tool performed representative cuts along the direction of the rail highlighted in Figure 5.

The scenarios included for simulation are detailed in Table 4. These included using cuts for preventative straight grinding taking 0.1mm of material off the entire rail head. These were performed using three different tooling setups in simulations 1-3. Simulations 4 and 5 investigate the operation to create the rail gap on curves using two different tooling setups. It should be noted that the number of cuts is also included in the Table, and represents the number of times that a grinding stone at a given angular position is required to pass over the rail head in order achieve a 0.1mm depth of cut. This information, along with the facet width of the cut, can then be used to estimate the total number of grinding wheels required in the grinding train.

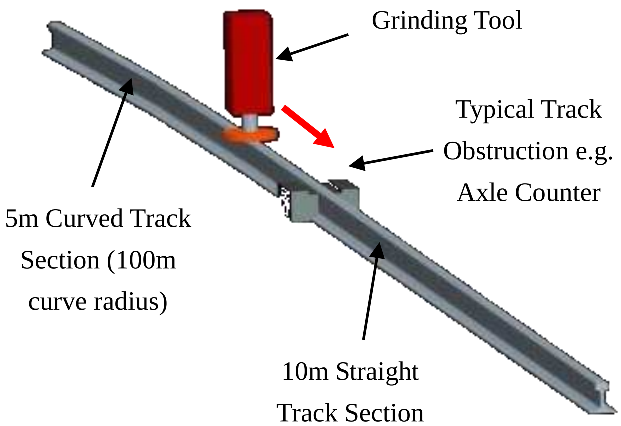


Figure 5. Simulation Set-up (image captured from Pro-Engineer)

6.2 Results

The results of the simulations look at the effect of gouging any part of the desired geometry for the particular cut setup. Gouging in a CAD/CAM environment indicates where a cutting tool, i.e. grinding wheel, removes more material than is desired from a defined cut line. Excess is where material remains above a defined cut line. The main aim of the simulation was to assess the effect of changing grinding techniques on potential interference with trackside obstacles and gouging of the rail profile. The results from the simulations are summarised in Table 5.

The results show that the gouging effects from any of the processes are not major providing results of between 10 and 25microns. Gouging of 22mm is detailed for the axle counter obstruction but in practice the grinding stones are raised above when encountering these obstructions. This result was included to highlight the benefit of a peripheral application in this case. There is no gouging when peripheral grinding is performed using wheels of 11inch diameter. This is obviously the preferential choice from the perspective of avoiding rail gouging but does require the grinding stones to be placed at angles beyond the current limits of some of the grinding trains. Face grinding always creates some interference when traversing a curved section. Although not large in value this will put added load on the wheel and increase the power requirement from the spindle. Face grinding also has more chance of interfering with track side obstructions but the placement of the grinding wheel could be adjusted to avoid this. Neither option provides significant problems with respect to rail gouging but the peripheral grinding orientation is the optimum solution when considering the kinematics of the process.

Table 4. Simulation Scenarios Investigated

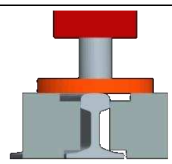
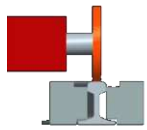
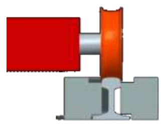
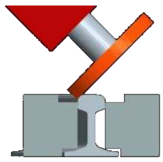
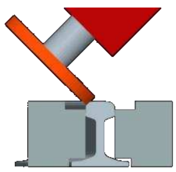
Simulation Number	Type of Track Maintenance	Wheel Orientation	Number of cuts	Image
1	Straight	Face Grinding	3	
2	Straight	Peripheral Grinding	3	
3	Straight	Full Profile Grinding	1	
4	Curves	Face Grinding	1	
5	Curves	Peripheral Grinding	1	

Table 5. Summary of Gouging Results

Simulation Number	Track Maintenance Type	Grinding Type	Gouging – Straight Section (mm)	Gouging – Curved Section (mm)	Gouging – Track Side Obstructions (mm)
1	Straight	Face	No Gouging	0.017 – Inner Rail	22.0 – Gauge and Field Side
2		Peripheral		No Gouging	No Gouging
3		Full Profile		0.025 – Inner Rail	No Gouging
4	Rail Gap	Face		0.013 – Inner Rail	No Gouging
5		Peripheral		No Gouging	No Gouging

7 CONCLUSIONS

The following conclusions were drawn from the work:

- The opportunity exists to improve upon the current process performance. The potential for a 100% increase in train speed for all preventative re-profiling operations exists.
- HEDG technology provides the best opportunity for a performance increase in preventative re-profiling operations where high train speed is desired to reduce maintenance costs.
- The biggest risks/challenges in employing HEDG is the introduction of plated CBN wheels to a grinding train. This requires high spindle speeds for effective application beyond the current maximum defined. More power available in the spindle is also required for increases beyond the theoretical 20mph calculated.
- Specific grinding energy, power and chip thickness are the governing parameters for designing a rail grinding process. As shown in calculations for specific grinding energy and chip thickness, a theoretical 100% increase in train speed is achievable by utilizing the specific grinding energy associated with HEDG grinding of steel using current power constraints. This is dependent upon the correct grinding set-up conditions.
- Further performance increase in either cut width or train speed requires additional spindle power.
- Reduced chip thickness is beneficial to the grinding process with respect to wheel design requirements and resistance to wear.
- The chip thickness experienced by grinding grains is reduced for a peripheral grinding setup and high wheel surface speeds. The application of HEDG technology cutting on the periphery of the wheel also provided optimum conditions during CAD/CAM simulation to avoid rail gouging, and any potential collision of the grinding stone with the modelled track side obstructions.

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