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A cutting pick for tunneling roadheaders to improve sustainability

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ABSTRACT: Cutting picks for Roadheaders are the main consumable when excavating rock and as such will be worn and discarded as part of the rock cutting process.

Through reducing downtime, by eliminating a current maintenance requirement via significant improvements in sleeve wear life and providing a universal one style pick, cutting picks can provide reductions in waste generation.

The collaborative relationships between tunnel operations and the Original Equipment Manufacturer (OEM) consumable provider is key in being able to deliver these benefits. This is achieved through new product trials, providing feedback on new concepts and their ability to make a difference.

This paper will provide an overview of a new universal cutting pick that provides less downtime and maintenance requirements thus improving the overall sustainability for tunneling operations.

1 INTRODUCTION

Roadheaders, refer to Figure 1, when excavating rock to produce a tunnel cannot do so without the use of cutting picks.

Figure 1. Sandvik MT720 Roadheader excavating rock.

The Roadheader and cutting pick market is important to Sandvik, following on from inspirations highlighted during a previous carbide trial there is an opportunity to provide the market with a new style of pick. This pick will increase sleeve life, reduce maintenance downtime, provide easier/safer pick replacement, decrease inventory requirements and promote the benefits of working with an OEM.

1.1 *Cutting Picks*

A typical cutting pick for tunneling is conical in shape and consists of three main components, referring to Figure 2, Roach & Claesson. 2023.:

- The carbide
- The body (Head and Shank)
- The retainer

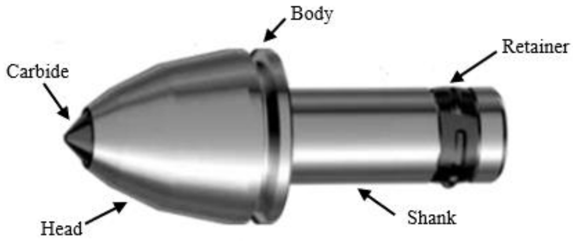

Figure 2. Typical Cutting pick components.

2 DEVELOPMENT AND PROTOTYPING

This new style pick will be categorized as a Full Length Retainer Roadheader (FLRRH) pick. As part of its development the FLRRH pick considered each of the typical cutting pick components.

2.1 *The Carbide*

The carbide for the FLRRH pick development was left to the current tried and proven carbide, which is a Sandvik premium grade (648) used for cutting medium to hard rock, in the form of an NP39 insert, referring Figure 3.

Figure 3. NP39 Carbide Insert.

2.2 *The Body - Head*

The pick head profile was reviewed for its cutting efficiency and body wash characteristics based on the data recorded during a previous carbide trial, Roach & Claesson. 2023. The head profile was reduced in size to allow a sharper cutting profile by removing excess material that also provided no additional benefits in the overall efforts to eliminate body wash, referring Figure 4 versus Figure 5, for the current head profile compared to the proposed new concept.

Figure 4. Current Sandvik Head Profile.

Figure 5. New Concept Head Profile.

2.3 *The Body - Shank*

The pick shank was then assessed for what the effect of reducing its cross sectional area would be to allow the utilisation of a full length retainer. From past history and knowledge, a 15% reduction in cross sectional area was deemed to be acceptable for the initial concept development that would be validated later in proof of concept trials.

The final concept design of the pick shank will need to complement the features of the full length retainer.

2.4 *The Retainer*

The concept of a full length retainer on a pick is not new, they have been employed on small Road Planer picks for some time. Road Planer picks are used to remove the surface layer of a pavement to allow a new surface to be directly overlaid on the existing base layers.

Developing a full length retainer for a Roadheader though would have to encompass a few different considerations:

- The larger size of the pick
- Significant increases in cutting and tangential forces on the pick
- The increase in inertia forces and the variations in force direction
- The environmental effects of cutting fines and slurry

The first design step was trying to understand how different designs would affect the retention ability of the full length retainer. 3D printing was used to check several different design concepts for their retention effectiveness. Four concepts were printed in 3D. The terminology used to describe the various features are noted in Figure 6

To test the retention ability of the 3D printed full length retainer concept designs, they were assembled on a pick shank, then installed in a sleeve and push tested in a Universal Test Machine. A summary of the push test results can be seen in Figure 7.

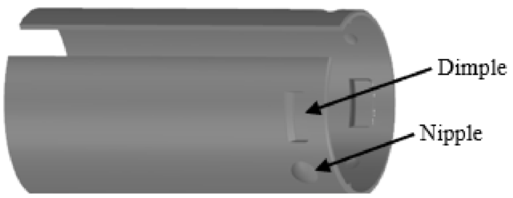

Figure 6. Dimple and Nipple feature designations.

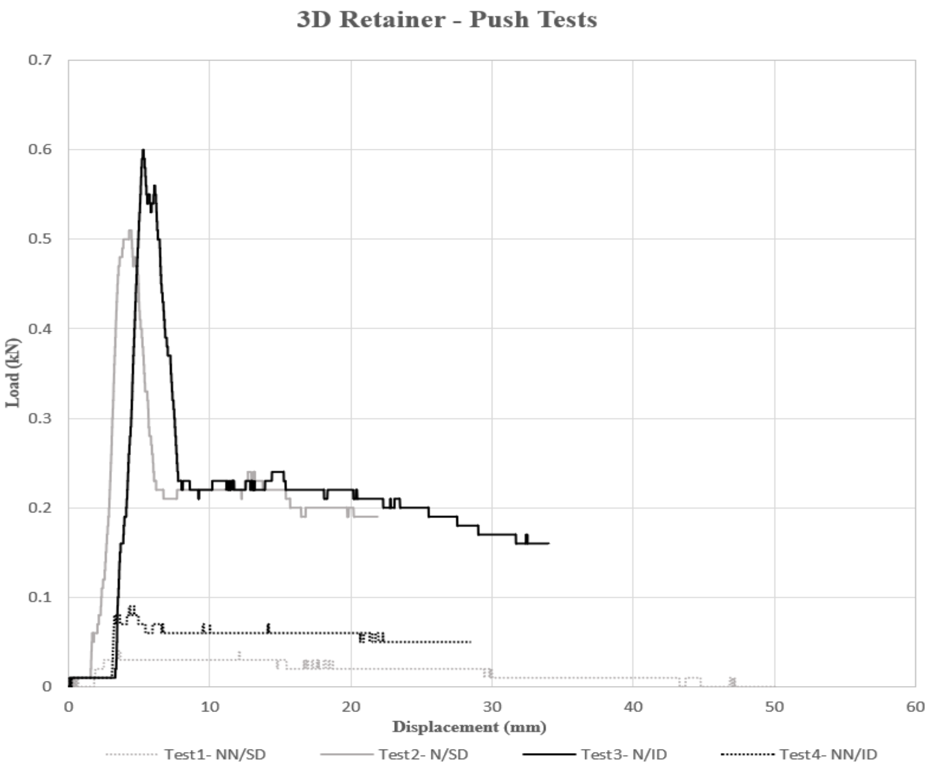

Figure 7. Summary of 3D printed full length retainer push test results.

The testing showed that there was a significant difference in the peak retention load between the full length retainer with a nipple (N) versus the full length retainer without a nipple (NN). The tests also showed that a full length retainer with an increased “at rest” diameter (ID) had a higher retention load versa a Full Length Retainer with a standard diameter (SD).

The next step was to establish what the baseline retention force of a steel version of the full length retainer should be.

The method chosen to determine this was to take the average retention force of the two current 38 mm picks, the P7JU-3885-1962, a friction retainer pick, and the P4AA-3885-3962, a bumped “Dog Collar” retainer pick, referring Figures 8 and 9.

Figure 8. 38 mm - Short Friction Retainer.

Figure 9. 38 mm Bumped “Dog collar” Retainer.

A summary of the test results can be seen in Table 1.

Table 1. Baseline Design Perimeter Determination.

Test Number	Pick/Retainer Sample	Load (N)	Comments
1	P7JU-3885-1962	1560	Short friction retainer
2	P4AA-3885-3962	1630	Bumped “Dog Collar” retainer

The baseline tests showed similar retention loads, closer than predicted, between the two current pick/retention options and set the pass goal, for retention, of the new pick at $\geq$ 1595 N.

To evaluate the retention performance of steel prototype full length retainer concepts, tests were performed in a Universal Test Machine with a similar set-up to that used before for the 3D printed concepts.

There were five steel prototype concept retention tests conducted in a new sleeve. They were:

- Prototype#1_1 - (SN)*
- Prototype#1_2 - (SN)
- Prototype#2_1 - (SNN)**
- Prototype#2_2 - (SNN)
- Prototype#1_2.2 - (SN)

*SN = Sandvik sleeve, Retainer with nipple.
**SNN = Sandvik sleeve, Retainer with no nipple

A summary of the test results can be seen in Table 2.

Table 2. Prototype#1 retention performance tests in a new sleeve.

Test Number	Pick/Retainer Sample	Load (N)	Comments
1	Prototype#1_1-(SN)	2520	The pick could be started in sleeve by hand but had to be tapped home with a hammer.
2	Prototype#1_2-(SN)	2110	The pick could be started in sleeve by hand but had to be tapped home with a hammer.
3	Prototype#2_1-(SNN)	1080	The pick could be installed in the sleeve by hand.
4	Prototype#2_2-(SNN)	1090	The pick could be installed in the sleeve by hand.
5	Prototype#1_2.2-(SN)	2140	The same pick assembly as used in Test#2 was tested a second time. The pick could be started in sleeve by hand but had to be tapped home with a hammer.

To gain a further understanding of the overall retention performance of the Prototype#1 full length retainer samples, retention tests were also conducted and compared against the retainers currently being utilised, in a worn sleeve. The tests were again performed in the Universal Test Machine with a similar set-up to that used before.

There were four retention tests conducted in a worn sleeve. They were in the form of:

- Prototype#1_1 - (SN)_WS***
- P4AA-3885-3962_WS
- P7JU-3885-1962_WS
- Prototype#1_2 - (SN)_WS

***WS = Worn sleeve

A summary of these test results can be seen in Table 3.

Table 3. Retention performance comparison tests in a worn sleeve.

Test Number	Pick/Retainer Sample	Load (N)	Comments
6	Prototype#1_1-(SN)WS	1510	The pick could be started in the sleeve and then push in by hand, except the last ~15 mm which had to be tapped home with a hammer.
7	P4AA-3885-3962WS	970	The pick could be started in the sleeve and then push in by hand, except the last ~5 mm which had to be tapped home with a hammer.
8	P7JU-3885-1962WS	1270	The pick could be started in the sleeve and then push ~25 mm in by hand, the last ~50 mm had to be tapped home with a hammer.
9	Prototype#1_2-(SN)WS	2030	The pick could be started in the sleeve and then push in by hand, except the last ~ 15 mm which had to be tapped home with a hammer.

The tests showed positive outcomes for the Prototype#1 retainer, achieving the retention baseline of $\geq$ 1595 N and performing well in the worn sleeve, when compared to our current picks.

3 PROOF OF CONCEPTS

To evaluate the system performance of the first production samples of the FLRRH picks in the field a proof of concept trial was conducted at a tunnel project in Sydney, Site 1.

Twelve FLRRH picks were installed in a Sandvik MT720 Road Header, after it had completed its cut cycle, to:

- Check the installation of twelve concept FLRRH picks and, more importantly, the removal of them at the end of the trial.
- Check that the concept FLRRH picks perform as required during operation, i.e.:
  - Are retained and rotate freely in the sleeve
  - Wear evenly

Twelve existing picks were removed from their locations and then the twelve concept FLRRH picks were installed in their place to form a line across each cutter drum.

The Roadheader cut on and off for approximately 10 hours, with an estimated actual cut time of ~7 hours. After the Road Header had completed its cutting cycle, it was trammed back from the face, parked, shutdown and isolated. The cutter head was then washed down, and the condition of the picks/sleeves/drums inspected. The twelve concept FLRRH picks were then removed.

The results showed that the FLRRH picks achieved the desired outcomes of the proof of concept field trials:

- The picks were installed and were removed successfully
- The picks performed functionally to the design requirements
- There were no failures of the pick system or any of its components

4 PRODUCT LIFE MEASUREMENT TRIALS

The goals of the life measuring trial were to:

- Obtain measurements of the bore of the sleeve, over time, to determine the effectiveness of the full length retainer to limit the wear in the bore of the sleeve, i.e. limit the bore wear.
- Continue to monitor the installation and the removal of the FLRRH picks after they have worn
- Check that the FLRRH picks continue to perform as required during operation, i.e.:
  - Rotate freely in the sleeve
  - Are retained in the sleeve
  - The full length retainer lasts beyond the life of the picks
  - Both the carbide and pick body wear evenly during the life of the pick

The initial evaluation was conducted at Site 1, where twelve existing picks were kept in their place to form a line across each cutter drum to act as a baseline, and then FLRRH picks were installed in every other location in each cutter drum. Both cutter drums had been fitted with all new sleeves.

This trial was stopped early though due to some of the full length retainers failing to retain the picks in the sleeves prior to the pick's complete wear life being achieved. This trial also highlighted the significant forces the system needed to cope with that could not be simulated in a laboratory environment.

After investigations the results showed that the FLRRH picks were not that far away from achieving the desired outcomes, so a re-design of the full length retainer was conducted.

An evaluation trial was conducted at Site 1 where twelve FLRRH picks with a re-designed retainer were installed in a line across each cutter drum, and existing picks were installed in every other location in each cutter drum to act as a baseline. Once again, the drums had been fitted with all new sleeves prior to the trial commencing.

This trial ran for 3 weeks and showed very positive results, with the re-designed full length retainer. Unfortunately, the sleeve wear benefits were not able to be quantified during this trial so a further trial would need to be organized to achieve this.

A second tunnel project in Sydney was approached, Site 2, and they were willing to allow a longer life measuring trial to be conducted.

Two complete drums, with new sleeves, were fitted with the latest FLRRH picks. The picks were inspected regularly and when a pick needed replacing the inner bore of the sleeve was measured. The trial was going well with minimal signs of bore wear in the sleeves. After about a month it was reported that some full length retainers were being left behind in the sleeves when the FLRRH picks were being replaced. After investigation and discussions, a tweak was made to the FLRRH pick shank. These latest FLRRH pick samples performed well and all ongoing trial FLRRH picks were made and supplied to this design. These FLRRH picks were then also introduced to a third site, Site 3, to gain more feedback and sleeve wear data. The results from Site 2 and 3 showed that the full length retainers are now lasting beyond the life of the picks.

From a system's life measuring perspective, the bore wear of the sleeves were measured and tracked over a 4 month period at Site 2, on a Sandvik Roadheader, and then at Site 3, on a Sandvik Roadheader for another period of 4 months.

Figure 10. Final FLRRH pick design

The life measuring trial was a success demonstrating the benefits of the FLRRH pick, referring Figure 10, on enhancing the wear life of the bore of the sleeves and eliminating this bore wear as a maintenance consideration in tunnel projects.

A summary of the bore wear per sleeve type can be seen in Table 4.

Table 4. Average bore wear per sleeve type.

Site	Sleeve Type	Bore wear (mm)	Time period (Weeks)	Average wear (mm)	Comments
2	Standard Sandvik	0.01 to 0.3	19	0.1	
3	Standard Sandvik	0.2 to 0.9	10	0.4****	
3	Sandvik Large Head	0.2 to 0.3	11	0.2	
3	Third Party	0.3 to 0.4	7	0.3	

**** Standard "Dog collar" style picks ran in these sleeves for ~ 2 weeks prior to FLRRH picks being installed

The final validation trial was to test the FLRRH pick in a Mitsui Roadheader. The goals of this trial were to:

- Observe the wear/effect on the tail of the FLRRH pick that protrudes from the back of the block and sleeve on the Mitsui Roadheader drum, refer Figure 11
- Monitor the installation and the removal of the FLRRH picks after they have worn
- Check that the FLRRH picks continue to perform as required during operation, i.e.:
  - Rotate freely in the sleeve
  - Are retained in the sleeve
  - The full length retainer lasts beyond the life of the picks
  - Both the carbide and pick body wear evenly during the life of the pick

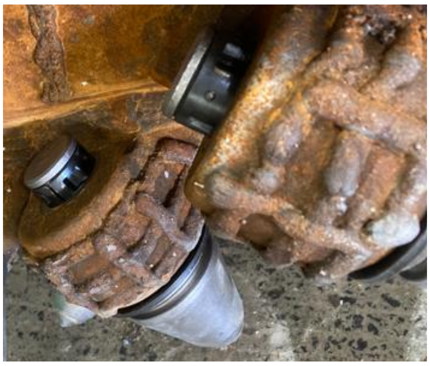

Figure 11. FLRRH picks installed in Mitsui Roadheader drum

The trail was a small initial trial at a tunnel project in Melbourne, Site 4, that involved installing six FLRRH picks in a Mitsui’s cutter drum alongside the currently used picks and observing them until the first FLRRH pick needed to be replaced. All six FLRRH picks were then removed for analysis.

The trial was a success with no abnormal wear on the tail of the FLRRH pick observed. The washer on the FLRRH pick protected the block equivalent to that of the large base head on the current picks.

So, in summary the outcome of the trials in the Sandvik and Mitsui Roadheaders were a success. They showed that the FLRRH picks:

- Perform as required during operation in both the Sandvik and Mitsui Roadheaders
- Installed, safely hands free, and were removed easily with either a pick puller or a slide hammer throughout the trials
- Eliminated bore wear in sleeves as a maintenance consideration
- Prevented the wastage of picks being thrown from worn sleeves on Sandvik Roadheaders

5 SUSTAINABILITY IMPROVEMENTS

The sustainability outcomes for the FLRRH pick on a Sandvik Roadheader were:

- Reduced downtime, with respect to changing sleeves, per Roadheader
  = -77 hours/year = 96.25 % less downtown on not having to replace sleeves due to worn bores
- Reduced sleeve consumption per Roadheader
  = 486 less sleeves/year = 96.4 % reduction of the current sleeve usage/year
  Note: Sleeves would only be changed now, using the FLRRH pick, due to the wear on the outside of its head, not its bore
  Savings of 894 kg CO_2-eq /year per Roadheader
- Reduced pick wastage per Roadheader
  = 96 less picks/yr = 100 % less of the current pick wastage/year
  Note: No FLRRH picks are lost due to worn sleeve bores
  Savings of 782 kg CO_2-eq /year per Roadheader
- Extra sustainability benefits:
  - Weight reduction
    = 15 kg CO_2-eq per 120 picks
  - Transport emissions are reduced due to reduced sleeve and pick usage
    = 357 kg CO_2-eq per Roadheader
  - End-of-Life emissions are decreased due to reduced sleeve usage and pick wastage
    = 29 kg CO_2-eq per Roadheader
  - Circularity - Resource Efficiencies due to less material demand
    = 1347 kg of material/year (Steel and Carbide) per Roadheader

In summary:

- Total annual emission savings
  = 2062 kg CO_2-eq /year per Roadheader
- Total annual resource efficiency
  = 1347 kg of material/year (Steel and Carbide)

6 CONCLUSION

This paper has provided an overview of the development of the Sandvik FLRRH pick from its various iterations through the concept and trial stages.

The Sandvik FLRRH pick proved its ability to reduce the wear in the bore of the sleeve to a level that actually eliminates this wear life as a maintenance consideration in tunnel projects, thus providing overall reductions in downtime, sustainability benefits and waste generations reductions.

The effectiveness of the full length retainer to limit the wear in the bore of the sleeve was exceptional and showed that it could also be a true universal, one pick fits all, inventory reducing solution.

7 ACKNOWLEDGEMENTS

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8 REFERENCES

Roach, W, Claesson, B (2023). Roadheader cutting tool developments towards sustainability. *Trends and Transitions in Tunnelling; 18th Australasian Tunnelling Conference*: 525-534.