Influence of Crushing Process Variables on the Product Quality of Crushed Rock
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Keywords

ABSTRACT

In many instances rock crushing has considered to be more art than science. One reason for that is that this industry is on global basis such a small niche, that companies involved have not had resources and on the other hand also no real need to study what is happening inside the crusher. Recently there has been put more emphasis on issues like the shape of crushed product. These requests are stated by end users of aggregates.

Idea to make this thesis is related to author’s deep involvement to the development of rock crushing equipment and especially cone and gyratory type of crushers. These crushers are the most critical ones if we think to have maximum impact on end product shape. In the development of cone crushers it is very important to know the impact of different crusher variables to the end product quality. By knowing the impact of different parameters, the basic key development requirements and goals for the new products can be stated. The basis parameters which can be played with are, providing that rock characteristics can be held constant: feed distribution, crushing cavity type and shape to be used, crusher stroke, speed, setting and choke feeding.

The objective was to clarify the relative importance of these parameters and for this purpose there were 72 tests made in full scale crushing plant application. From the measured values there were calculated some clarifying values in order to have wider perspective to interpret the results and draw conclusions.

Based on these tests it can be said that the feed characteristics is the first and most important determinator as to the end product quality. Influence of other parameters is dependable on feed characteristics, and is shown in detail in the thesis. This means that although end product quality can be improved by changing the crusher’s operational parameters (stroke, speed, setting, cavity) but they hardly can compensate poor product shape if crushing process is faulty, meaning wrong feed distribution to the crusher or crusher is not being choke fed.

In this thesis attempt has been made to incorporate all process- and crusher variables together and thus from wider perspective to rank the influencing parameters to priority order in different applications. Although this study has been reasonably extensive, this is still considered to be a basis for future research and development.
PREFACE AND ACKNOWLEDGEMENTS

This thesis is done at Nordberg Lokomo in Finland, which belongs to Nordberg Group, the global leader in developing crushing equipment for construction, mining and recycling industries.

The starting point has been to have most comprehensive approach for the one of the major technical success criteria for the future: How to produce cubical aggregate. This issue has been studied by several authors, but this thesis differs from the others by trying to integrate better the influencing parameters with each others.

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Jarmo Eloranta
Table of Contents

ABSTRACT

PREFACE AND ACKNOWLEDGEMENTS

DEFINITIONS

LIST OF SYMBOLS

1 INTRODUCTION
   1.1 Background of the thesis
   1.2 Objectives and the scope of the thesis
   1.3 Research methods

PART ONE
ISSUES RELATED TO THE PRODUCTION OF CUBICAL PRODUCT

2 INTRODUCTION TO CRUSHING AND CRUSHERS
   2.1 Application range for crushers
   2.2 General principles of crushing process planning
   2.3 Review to different crushers

3 CRITERIA FOR CUBICAL PRODUCT
   3.1 Why cubical product is needed
   3.2 Review to different standards

4 CRUSHING THEORY IN GENERAL
   4.1 Crushing chamber performance
   4.1.1 General
4.1.2 Crushing phenomena
4.1.3 Influence of bulk density
4.1.4 Other influencing factors
4.1.5 Energy input
4.2 Particle fall through crushing cavity
4.3 Crushing forces in cone & gyratory crushers

5 LITERATURE REVIEW TO PRODUCE CUBICAL PRODUCT
5.1 Background of rock breakdown
5.2 Influence of rock properties
5.3 Impact of crushing parameters
5.3.1 Crushers types
5.3.2 Feed
5.3.3 Crushers' operational parameters
5.3.4 Other factors

PART TWO
RESULTS OF CRUSHING TESTS

6 TEST ARRANGEMENT
6.1 Test program
6.2 Plant configuration and test runs
6.3 Recorded test data

7 BACKGROUND FOR SELECTED PARAMETERS
7.1 Selected parameters
7.2 Number of crushing zones and work stroke
7.3 Impact speed against the rock
7.4 Further clarification of some parameters

8 TEST RESULTS
8.1 Results in general
8.2 Analysis systematic
8.2.1 Tests 56-67
8.2.2 All cavities according to each feed
8.2.3 Influence of input parameters
8.3 General summary of tests

9 VERIFICATION OF TEST RESULTS TO PREVIOUS TESTS

10 DISCUSSION
10.1 Evaluation of the validity of results
10.2 Evaluation in respect to previous studies
10.3 Recommendation guidelines with limitations
10.4 Needs for further research

11 CONCLUSIONS

REFERENCES

APPENDICES
Appendix 1: Stone study report
Appendix 2: Plant flow sheet
Appendix 3: Example of power and pressure measurement
Appendix 4: Example of screen analysis
Appendix 5a-c: Feed and product curves
Appendix 6: Example of crushing cavity calculation
Appendix 7: All tests with calculated parameters
Appendix 8: Tests 56-67 classified according to cubicity
Appendix 9: All tests classified according to cubicity
Appendix 10: Tests 56-103 classified according to stroke
Appendix 11: Tests 56-103 classified according to speed
Appendix 12: Tests 56-103 classified according to setting
Appendix 13: Tests 104-127
DEFINITIONS

The following definitions and terms have been used in this thesis:

Cavity change: The chance of cavity volume between different crushing zones.

Choke feeding: This means that sort of feeding arrangement to the crushe that
cushing cavity keeps full.

Choke point: The point in the crushing cavity where the volume of the material to be
-crushed is smallest. This determines the capacity of the crushe.

Closed circuit: Crushing process feature, where part of material produced by crushe
-of circulated back to the same crushe to be further crushed.

Cone head: Conical part which supports liner.

Concave: The external part of tools to be used for crushing

Critical speed: Speed is critical, when cone head oscillation speed is the same as the
-falling speed of crushed material.

Crushing cavity: The space between liner and concave where crushing action itself
-takes place.

Crushing ratio: Ratio between feed and outcoming product. It is normally measured
-of 80% point; Crushing ratio = Feed_{80}/Product_{80}. This describes the
-work which has been done from feed to product.

Crushing zone: When material is being crushed, it descends through cavity from one
-crushing zone to another zone.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>CSS:</td>
<td>Closed side setting, minimum distance between liner and concave at the discharge end of cavity.</td>
</tr>
<tr>
<td>Cubicity:</td>
<td>Describes the shape of rock. There are different standards available. In this thesis DIN standard is being used.</td>
</tr>
<tr>
<td>Flakiness index:</td>
<td>Describes the shape of the rock. Basically same as cubicity.</td>
</tr>
<tr>
<td>Interparticular crushing:</td>
<td>Rock crushing takes place against each other and not only against the crushing tools.</td>
</tr>
<tr>
<td>Liner:</td>
<td>The inner part of tools to be used for crushing. Fitted on cone head.</td>
</tr>
<tr>
<td>Nip angle:</td>
<td>Angle between liner and concave when rock is caught, nipped, between them.</td>
</tr>
<tr>
<td>Nominal stroke:</td>
<td>See stroke</td>
</tr>
<tr>
<td>OSS:</td>
<td>Open side setting, maximum distance between liner and concave at the discharge end of cavity.</td>
</tr>
<tr>
<td>Packing:</td>
<td>Happens when rock is being compressed so much that its density has increased so much that it starts to be solid.</td>
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<tr>
<td>Pivot point:</td>
<td>The point around which cone head is oscillating, center of the crusher's top bearing, if such crusher type.</td>
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<tr>
<td>Reduction ratio:</td>
<td>Same as crushing ratio.</td>
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**Segregated feed:** Feed to the crusher is such that fine and coarse particles in the feed get to the different side of the crushing cavity.

**Shape factor:** Same as flakiness index and cubicity.

**Stroke:** Difference between OSS and CSS.

**Work stroke:** The distance between CSS and the distance when material compression starts.
LIST OF SYMBOLS

A = crushing zone area
C = constant
E = Energy (kWh/t)
N = speed of cone head (RPM)
P = power (kW)
P_{80} = crushed product (mm, 80% by weight passing)
F_{80} = feed size (mm, 80% by product passing)
R = distance of crushing zone from centerline
S = stroke (mm)
t = time (s)
V=Y = contact speed against falling speed (m/s)
Y = work stroke (mm)
W_i = work index (kWh/shortton)
W = work in kilowatt hours (kWh)

\( \rho \) = material density
\( \sigma \) = tensile stress (N/mm\(^2\))
\( \tau \) = shear stress (N/mm\(^2\))
\( p \) = compressive stress (N/mm\(^2\))
_ = direction of resultant crushing force (deg)
\( \omega \) = angular speed (rad/s)

Subscripts

m = maximum
i,j,k = indices
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11 CONCLUSIONS

The extensive tests performed and the analysis based on them supported the initial hypothesis of this research in the respect that it would be possible to recognize the major operational factors influencing the shape of crushed product, and to classify these influencing factors in the order of priority. The factors which were found to correlate with product shape were:

* Feed gradation
* Crusher operational parameters:
  - Stroke
  - Speed
  - Setting
  - The length and shape of crushing cavity
  - Crushing force
  - Crushing ratio

The most important parameters which were found to have an impact on product shape are feed gradation and crusher (work) stroke. The remaining parameters do have an impact but less than these two. The impact of operational parameters were found to be different or even inverted depending on the feed gradation, and thus the influence of crusher operational parameters has to be evaluated together with feed gradation.

It was found that if feed does not contain enough fines, it is very difficult to compensate fully with other influencing parameters. This means that the crushing process configuration is very important, because the crushing process as a matter of fact adjusts the correct feed to the crusher. If some of the operational parameters of crusher cannot be optimally selected for product shape, the adjustments to feed curve can compensate the shortcomings in these parameters.

The impact of stroke actually means both increased compression and impact speed against the rock. When there were enough fines smaller than the setting in the feed, the particle shape of the product was good with larger stroke. On the other hand, when the feed did not include fines smaller than the setting the best particle shape was obtained with smaller stroke. In the first case where there were more fines in the feed, the larger stroke caused an effective interparticular crushing effect, and this rounded the particles with poorer shape. So major contribution of larger stroke in improving cubicity relates to utilization of existing fines in a feed as well as own production of fines for more effective interparticular crushing. In the latter case where there were no fines in the feed, the larger stroke caused a more 'violent' crushing action on the particles and the
outcome was a poorer shape, because finer support material as a damping material was not present. So in this case when the stroke was reduced, the crushing action became gentler, which improved cubicity. In cases where larger stroke can be used for better cubicity, there is a very important 'by-product': larger stroke gives bigger capacity, or then crusher size could be minimized due to larger stroke, and this is of course an important economical issue.

Speed variations investigated here did not show any clear influence regarding the impact on cubicity. If stroke and speed are compared together there is in both cases an increased impact speed against the rock but work stroke is bigger if nominal stroke is bigger. This seems to mean that impact speed itself is not so important, but if longer compression distance is involved the joint impact is positive.

Influence of setting can be expressed so that if there are fines in the feed the changes are improved to achieve higher cubicity values with smaller setting. Setting influences the crushing ratio as well as crushing force. As known, these may not be too high if no fines in the feed, and thus it means that better cubicity results can be expected with wider setting.

The tests gave some indications that the length of the crushing cavity has to be reduced in those cases where the feed contains fines, because otherwise there will be a danger of packing. Inversely if feed does not have fines, a longer cavity helps to increase the number of crushing zones, and thus it helps to produce the important fine support material which is missing from the feed.

As to the crushing ratio it was found that particle shape can also be good with higher crushing ratios providing that there is enough support material, i.e. fines, in the feed. This also relates to the effective interparticular crushing.

A smaller crushing force helps to improve cubicity, when there are no fines in the feed. The reason is that the crushing action is gentler. If there are fines in the feed the result is exactly the opposite: more force is needed to have effective interparticular crushing, because smaller particles need more energy to break.

Test results were compared to previous tests with the same crusher and liners as done at Nordberg-Lokomo's test plant. It was found that the major parameter, feed, correlate reasonably well with each other, although the rock type was different.

As a major conclusion it can be said that crusher operational parameters can influence the product shape within certain limits, but that the most decisive factor influencing cubicity is feed arrangement, which means that the major emphasis should be on the crushing process.


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