2009 American WJTA Conference and Expo
August 18-20, 2009 • Houston, Texas
Paper

THE ACCURACY OF THE KERF WIDTH PROFILES OF FACING SLABS AND MODERNIZATION OF EDGING MACHINES FOR AWJ CUTTING

J. Asatryan, Kh. Suvaryan
State Engineering University of Armenia
Gyumri, Armenia

ABSTRACT

The objective of this study is to determine the optimum parameters for cutting a kerf width profile during AWJ edging of facing slabs from natural tuff, travertine, marble, and basalt. The optimum cutting speed for these geometry profiles into various slab types is proposed. It has been established that the “barrel” taper is structurally the most interesting and expedient because it has most seismic resistance on buildings. The parameters of AWJ cutting for this case are also determined. Research carried out in recent years shows that during AWJ cutting of natural stone at a depth of 20-50 mm, it is possible to increase the cutting speed to up to 3,000 mm/min. These results were taken as a basis for modernization of diamond saw-based edge trimming machines for AWJ cutting. Projects were developed for modernization of cross-edging, cross-longitudinal, edge trimming and universal stone cutting machines produced by the “Stone Cutting Machine” company in Gyumri, Armenia.

Organized and Sponsored by the WaterJet Technology Association

1. INTRODUCTION

Despite the successful development of an AWJ cutting process on various areas of engineering and technology, production rates for mass manufacture of building elements is rather low. These elements include the production and processing of a natural stone to the correct form for building walls with adequate seismic stability and the edging of facing slabs.

Preliminary research of wall stone production using AWJ cutting from mountain rock with a adequate strength has shown a large potential for this use [1]. The rather small cutting efforts and energy expenditure of AWJ technology has allowed development of a special mobile stone cutting machine [2], which is favorably distinguished from existing heavy rail machines.

Research into the accuracy of a kerf width profile executed by M. Hashish [3], methods suggested for a reduced surface taper by angular compensation of an AWJ nozzle, and the optimum regimes for AWJ cutting of facing slabs from natural stone [4] were taken as a basis for retrofitting diamond-saw based edge trimming, cross-cutting, longitudinal-cutting and universal stone cutting machines for AWJ cutting. A case study measures the expediency of modernizing inexpensive stone edging machine tools.

The optimum kerf width profile for parts cut by AWJ technology is influenced by numerous factors, but the speed of submission is based on the cutting and thickness of the part. Depending on a combination of these parameters, four typical kerf forms are possible: taper or "V" shaped, reverse taper or "Λ", very little taper or "||", and barrel taper or "()" [5].

The profile of the docking surfaces of the facing slab and sidewalks parts listed in Figure 1 were produced by a special machine [2]. To a certain degree, raising the stability and seismic resistance of the faced vertical surfaces of walls depends on the quality of fastening (e.g. the mortar priest between slabs) and the cement slurry thickening. Theoretical and experimental researches shows that the masonry veneer of the "barrel" kerf profile is the most stable. Hence, determining optimal parameters for AWJ cutting ensuring this form at various part thicknesses is an important and urgent engineering task.

This paper documents research on the geometrical accuracy of a kerf width profile in tuff, travertine, marble, and basalt slabs with thicknesses ranging from 20 to 80 mm. This research indicates the cutting parameters for ensuring correct taper forms, in particular the "barrel" taper. A case study of the economics for retrofitting diamond saw edgers to AWJ stone cutting purposes using machine tools manufactured by "Stone Cutting Machine" in Gyumri, Armenia is also included.

2. KERF WIDTH PROFILE OBSERVATION

The three basic technical requirements for manufacturing facing slabs from natural stone surround geometrical accuracy: the straightforwardness of side edges, deviation of angular parameters, and kerf width profiles. In combination, these requirements determine to a certain degree the durability of fastening during construction. The first two requirements derive from the precision of parameters of the machine tool, but the third depends only on the processing conditions for AWJ cutting.

When assembled against metal parts, parameters of surface finish (such as waviness and roughness) do not play a role in durability or stability. But geometrical accuracy does positively influence coupling when stacking slabs with a mortar or glue. And of the four kerf width profile forms, stable fastening requires use of the "barrel" and "reverse" forms.

In this section we present the results of experimental research on kerf width profiles produced by AWJ cutting of slabs using tuff (a strength up to 30 MPa), travertine (a strength up to 60 MPa), marble (a strength up to 120 MPa) and basalt (a strength up to 150 MPa) with a focus on the quality of "barrel" and “reverse” forms.

Figure 2a show an experimental sample with a thickness between 20 to 80 mm on which the four sides were finished under four different conditions via AWJ cutting at nominal submission speeds of 10 to 100 %. Figure 2b shows an experimental sample where thickness was the only variation. Other experimental samples of rectangular forms with varying thickness were also considered. After performing AWJ cuts, we used a diamond saw to cut lateral surfaces for precise examination of the cutting's steady period and ease of measurement under a microscope.
The experimental samples are from quarries in Armenia. The samples had the structure and physical-mechanical proprieties defined in a standard reference book. The kerf width profile was performed on facing slabs of the previously mentioned four materials.

The AWJ cutting was made using an M-329/IFB machine produced by Flow International. Cutting parameters and conditions were maintained according to the following date: water jet pressure 3,300 MPa; abrasive: garnet mesh 80; concentration: 0.460-0.554 kg/min; nozzle size: 1.016 mm; orifice: 0.33 mm; water rate: 3.5 l/min.

The measurement results are recorded in characteristic tables. Figure 3 shows the measurements for facing slabs from tuff and travertine. This figure also indicates the thickness of experimental samples, nominal cutting speed $\mathbf{V}_{100}$ and its interval change from 10-100%. The speed $\mathbf{V}_{100}$ was chosen as it did not generate undercuts in the bottom. Each case graphs taper versus speed for barrel, reverse, and very little kerf width profiles. The normal or “V” taper is structurally not recommended for facing slabs and thus not graphed. It has also been established that the trail back and bottom waviness can introduce 10-20% error in the results of measurements.

The experimental analysis and processing of research results shows that:

- Cutting facing slabs from natural stone using an AWJ yields the principal regularities in quantitative and qualitative changes of the profile's geometry width similar to AWJ cutting of metal parts [3, 4].
- Given equal thickness of facing slabs, the inclination of “barrel” and “reverse” taper for relatively softer stones (tuff, limestone) is shallower than hard rock. For tuff, the “barrel” taper forms between 30 to 35 mm and cutting speeds of 2,300 mm/min and lower. Increasing the thickness of the slabs and reducing submission speed increases “barrel” taper yield.

- For stones of the middle hardness (travertine, marble), the “reverse” taper requires a thickness of 40 to 45 mm while a “barrel” taper is possible only at a lower submission speed of 300 mm/min.
- For the slabs from strong stone (basalt, granite) with a prevailing compact grain, the “reverse” and “barrel” tapers are possible with a slab thickness of 45 to 50 mm and a relatively elevated submission speed of 630 mm/min and below.

The taper graphs related to using AWJ cutting for edging facing slabs and sidewalks from natural stone are included the instruction manual for machine tools.

3. CASE STUDY: MODERNIZING STONE EDGING MACHINE TOOLS

The edging operation during manufacturing of facing slabs substantially influences the qualitative parameters of the production and occupies the longest time. Stone edging machine tools produced for CIS countries, in particular those produced by "Stone Cutting Machine" in Gyumri, Armenia, have simple kinematics, are reliable, and relatively inexpensive (10,000 USD or less). The machine tools AKM-12, AKM-14, AKM-15, and AKM-16 are intended for processing and edging facing slabs from natural stone of various forms and hardness, with thickness up to 60 to 80 mm. However, the diamond saw provides insufficient geometrical regularity of the kerf profile and the production cost is higher.

Our research into cutting facing slabs shows that the use of an AWJ for edging not only increases productivity with a submission rate of up to 2,000 mm/min, but also provides a geometric kerf profile important necessary for steady fastening of facing slabs on vertical walls and masonry veneer of sidewalks.

Analyzing the design of the previously mentioned machine tools and comparing this to tools dedicated for AWJ cutting shows both tool types use common base units. Thus retrofitting machine tools for AWJ cutting does not demand a large capital expense. Accounting for the necessary investment, retrofitted machine tools will be two to three times less expensive than dedicated AWJ cutting machine tools.

During the case study, various units from the benchmark companies were used [5, 6, 7, 8, 9]. The modernized machine tool AKM-12-W is intended for use by stone-working enterprises and for on objects of construction. The AKM-14-W is intended for cross-cut of the facing slabs. The machine tool AKM-16-W is for longitudinal edging of the facing slabs on both sides.

As an example of modernization, the AKM-15 edging machine in shown in Figure 4. The machine is installed on a stationary foundation and used in stone treating mills and quarry departments. The machine is a bridge-type design and has universal assignment. Besides edging and cutting operations, the machine can also carry out figured processing. The modernization is removing the diamond saw and replacing this with an abrasive cutting head assembly. The AWJ head can move and turn on three axes. The accessory drive is retained. The machine square faces the table with the article turned at 90^0. Other models for AWJ cutting can be retrofitted from existing machine tools.

4. CONCLUSION

1. In the earlier research it was show that “barrel” and “reverse” taper kerf profiles are the best for mating surfaces of facing slabs from the point of stability and seismic resistance.
2. The optimum parameters for AWJ cutting of these kerf profiles into facing slabs of varying thickness and composition, including tuff, travertine, marble, and basalt, have been observed.
3. It has been established that retrofitting diamond saw edging machine tools for AWJ cutting is economically expedient. A case study retrofitting examples from company "Stone Cutting Machine" in Gyumri, Armenia has been conducted.

5. REFERENCES

1. Asatryan J., (2007) " The Technology and the Machine for Cutting Wall stone of the Correct Form by Ultra-High Pressure Waterjets, Proceedings (CD Format) of the 2007 Waterjet Conference, WJTA, Houston, TX, August.
2. Asatryan J., Suvaryan Kh. “The machine for production a stone”. *Patent of Republic of Armenia*.- # A2 1839.- 2006.
3. Hashish, M., (2007) "Benefits of Dynamic Waterjet Angle Compensation", Proceedings (CD Format) of the 2007 Waterjet Conference, WJTA, Houston, TX, August.
4. Hashish, M. (1992) “A Modeling Study of Jet Cutting Surface Finish”, ASME *Proceedings on Precision Machining: Technology and Machine Development and Improvement, PED-Vol. 58, pp.151-167, November*.
5. www.omax.com.
6. www.wardjet.com.
7. www.kmt-waterjet.com.
8. www.ant-ag.net.
9. www.waterjet-SPB.

6. GRAPHICS

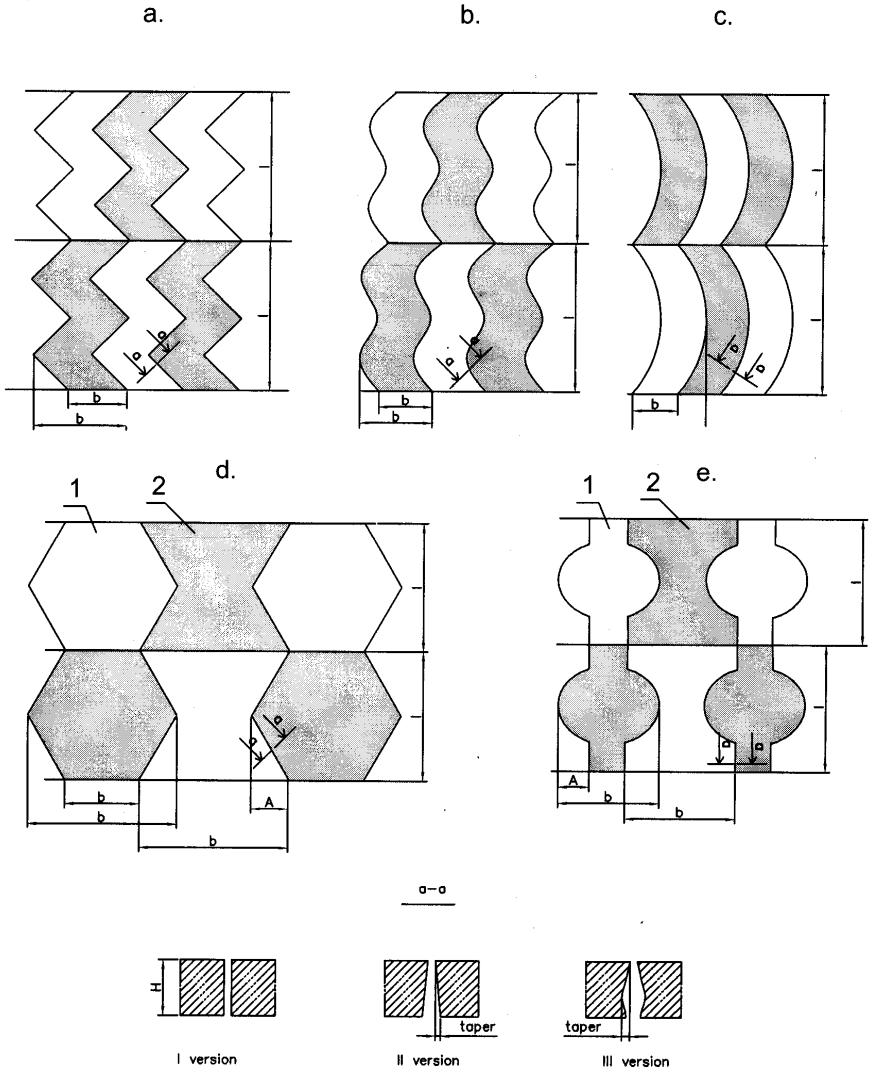

Figure 1. Profile of the docking surfaces of the facing slab and sidewalks parts.

a. **b.**

Figure 2. Experimental samples.

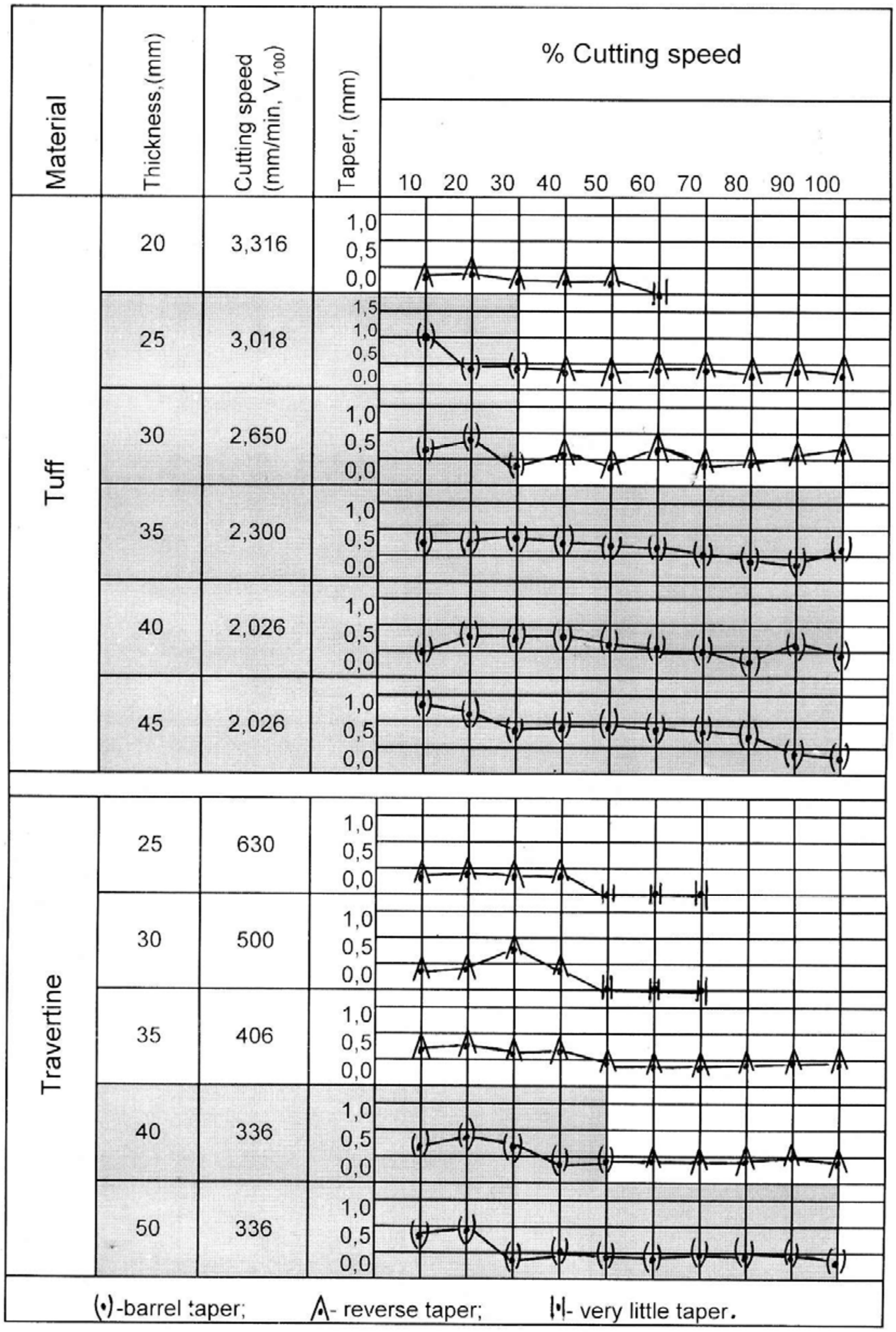

Figure 3. The impact of form, taper, thickness and material on cutting speed.

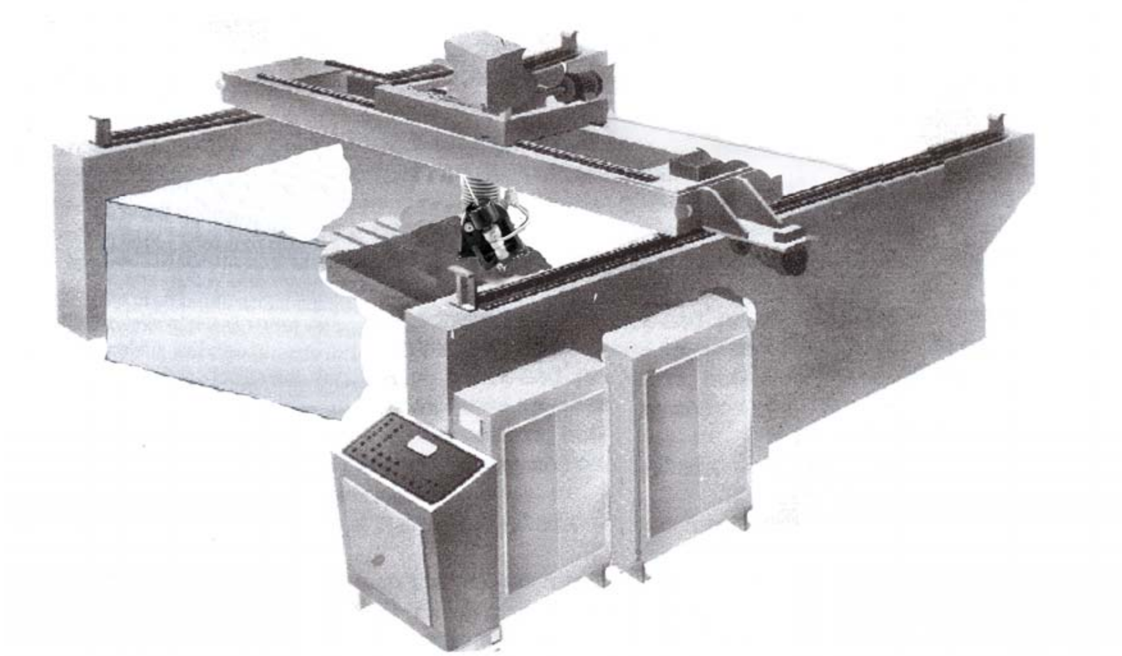

Figure 4. AKM-15-W edging machine modernized for AWJ cutting retrofitted.