P. HREHA, S. HLOCH, P. MONKA, K. MONKOVÁ, L. KNAPČÍKOVÁ,
P. HLAVÁČEK, M. ZELEŇÁK, I. SAMARDŽIĆ, D. KOZAK

ISSN 0543-5846
METABK 53(1) 29-32 (2014)
UDC – UDK 669.15:669:715:621.19:620.178.1=111

INVESTIGATION OF SANDWICH MATERIAL SURFACE CREATED BY ABRASIVE WATER JET (AWJ) VIA VIBRATION EMISSION

Received – Prispjelo: 2013-02-15
Accepted – Prihvaćeno: 2013-05-25
Original Scientific Paper – Izvorni znanstveni rad

The paper presents research a of abrasive waterjet cutting of heterogeneous "sandwich" material with different Young modulus of elasticity of the cutted surface geometry by means of vibration emission. In order to confirm hypothetical assumptions about direct relation between vibration emission and surface quality an experiment in heterogeneous material consisting of stainless steel (DIN 1.4006 / AISI 410) and alloy AlCuMg2 has been provided.

Key words: sandwich material, stainless steel, AlCuMg2, abrasive water jet cutting, surface

INTRODUCTION

Nowadays a number of methods and technologies designed for cutting of structural material exist. New requirements related to up-to-date material and its properties are constantly being laid on these methods. The development in this sphere has been reaching a rapid speed and composite or other heterogeneous materials have been achieving a remarkable prominence. As in the cross section of these materials after cutting significant changes of material properties occur, particularly in the case of modulus of elasticity, such a task may represent a considerable issue for the conventional technology. This drawback opens application possibilities for more versatile technologies including the abrasive water jet cutting technology. However, it is not the case of universal technology and even here passing of an instrument through materials of diverse moduli of elasticity may represent a certain problem.

STATE OF THE ART ANALYSIS

The issue of abrasive water jet cutting has been a subject to a long-standing development and research all over the world. Sano et al. [1] dealt with abrasive water jet cutting of amorphous alloys. The same used magnetic anticorrosive foils in the experiment. Later Zeng et al. [2] focused on cutting of polycrystalline ceramics. Wang et al. [3] elaborated a study on the cutting of coated materials by means of abrasive water jet including empirical models designed for prediction and performance of cutting. The use of oscillation head in composite material cutting was examined by Lemma et al. [4] through utilization of the GFRP composite. Another author dealing with the machining of composite materials by means of abrasive water jet was Azmir et al. [5] who applied the Taguchi's approach to a designed experiment and as an examined parameter the parameter of the generated surface Ra was used. Many authors devoted themselves to the alternatives of indirect control in the process of abrasive water jet cutting. Hreha et al. [6] dealt with vibrations in the cutting process as well and examined the relation between the vibrations of cutting material (aluminium) and parameters of surface roughness Ra, Rq and Rz. Further on, by means of vibrations, the same examined the processes occurring during the material penetration [7]. The aforementioned team of authors referred to the possibilities of utilization of vibrations as information carriers for on-line control of the process of abrasive water jet cutting and to utilization of the technology in the case of specific applications [7, 8].

MATERIALS AND METHODS

The experiment was performed in the conditions of real operation of abrasive water jet cutting on the three-axis table manufactured by the company of PTV (Table 1). A sandwich semi-product composing of two metal plates bonded together by epoxy adhesive was prepared as an experimental material. These plates were made of stainless steel with marking according to DIN 1.4006 (AISI 410) standard with thickness of 32 mm and of Al alloyAlCuMg2 with thickness of 20 mm. The sensors were placed as is shown in the Figure 1a.

The data were collected by the system of NI PXI – 1031, in the case of simultaneous eight-channel collection the system of NI PXI – 6109 with frequency of 30

P. Hreha, S. Hloch, P. Monka, K. Monková, L. Knapčíková, Faculty of Manufacturing Technologies, with a seat in Prešov, Prešov, Slovak Republic
P. Hlaváček, M. Zeleňák Intitute of Geonics Academy of Science v.v.i. Ostrava – Poruba, Czech Republic
I. Samardžić, D. Kozak Josip Juraj Strossmayer University of Osijek, Mechanical Engineering Faculty in Slavonski Brod, Croatia

Table 1 **Experiment set up**

Factors (Materials: DIN1.4006 (AISI 410) /AlCuMg2)	Values
Pressure *p* / MPa	350
Traverse speed *v* / mm.min^{-1}	50
Abrasive mass flow rate m_a / g/min	400
Orifice d_o / mm	0,14
Focusing tube d_f / mm	0,8
Standoff *z* / mm	3
Number of passes	1
Abrasive head angle cut / °	90
Abrasive type	Barton
MESH	80
Material thickness / mm	52

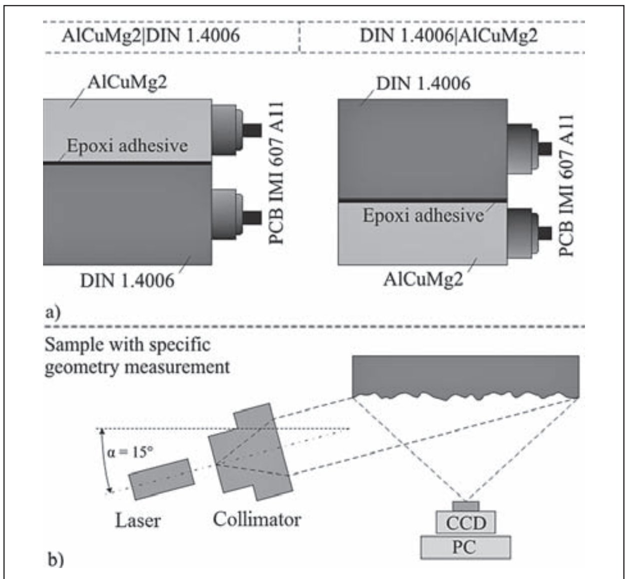

Figure 1 Experimental material and the generated surface topography scanning

kHz was used. The vibrations were scanned by means of the single-axis accelometers of PCB IMI 607 A11. The vibration signal was consequently analysed through the virtual instrument generated in the object programming environment of LabVIEW 8.5. The surface topography was scanned and analysed by means of optical profilometer of MicroProf FRT. The scanning principle is shown in the Figure 1 b.

RESULTS

In the course of the first cutting the experimental material was oriented upwards by means of the Al alloy plate. In the second cutting the orientation of material was the opposite one. The vibration signal was scanned from a side perpendicular to the cutting direction. The examined signal section lasted for 3 seconds. Time records of the scanned signal are shown in the Figure 2. The upper part of figure contains signals attributed to the first cutting (Figure 2, I sample). The signals of both layers of material possess similar development due to transmission of oscillations in the material. Records showed higher amplitudes of the signal scanned on the Al alloy plate in comparison to the signal from the sensor placed on the stainless steel plate. A few cases are exceptions to the aforementioned, e.g. negative amplitudes of oscillation after 2,5 seconds in the event of which higher values of deflection were recorded on the lower plate (stainless steel). The second part of Figure 2, II sample, shows time records of the vibration signal scanned in the course of the second experimental cutting. In this cutting the Al alloy plate was placed on the lower part of a workpiece.

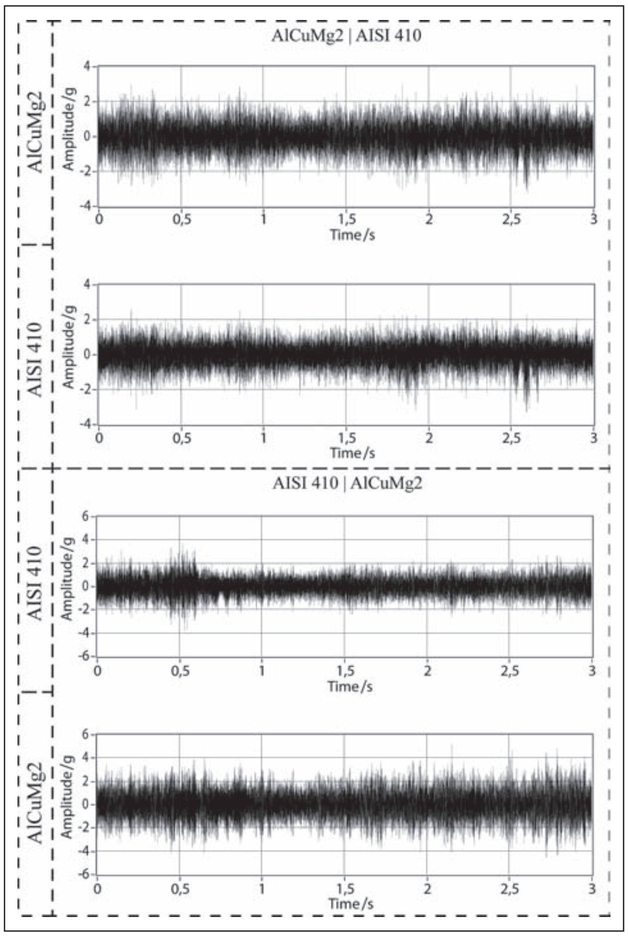

Figure 2 Time records of recorded vibration signals, *v* = 50 mm/min, m_a = 400 g/min, d_f= 0,8 mm

Difference of an amplitude level between signals from both layers was more apparent in this case. Higher amplitudes were again recorded in the case of softer material (Al alloy). That material was placed in the zone in which the abrasive water jet lost a high amount of kinetic energy due to passing through the material with higher modulus of elasticity (stainless steel). The results of frequency analysis of scanned signals are shown in the Figure 3.

The graphs in the figure are set out the same way as in the previous case. Even with the FFT spectra the graphs similar as to shape from both layers of material are possible to be seen. The differences are visible in the height of the recorded amplitudes. Higher values were detected with signals placed on the Al alloy plate. In the first cutting (upward workpiece orientation by means of Al alloy plate) in the Figure 3 I sample, high amplitudes on low frequencies ranging from 50 to 1 500 Hz were

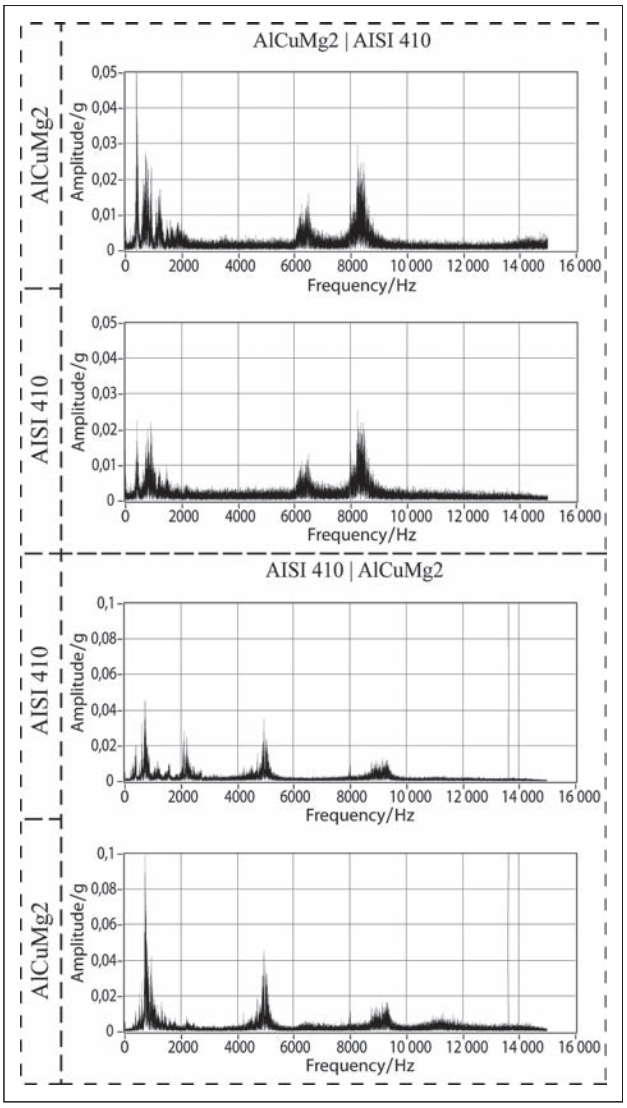

Figure 3 FFT spectra of the recorded vibration signals, v = 50 mm/min, m_a = 400 g/min, d_f= 0,8 mm

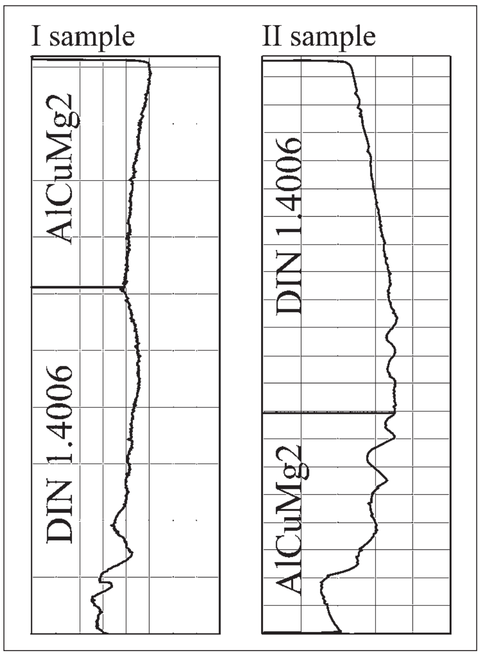

Figure 4 Profiles of the generated surfaces I sample AlCuMg2 / DIN 1.4006 , II sample DIN 1.4006 / AlCuMg$_2$

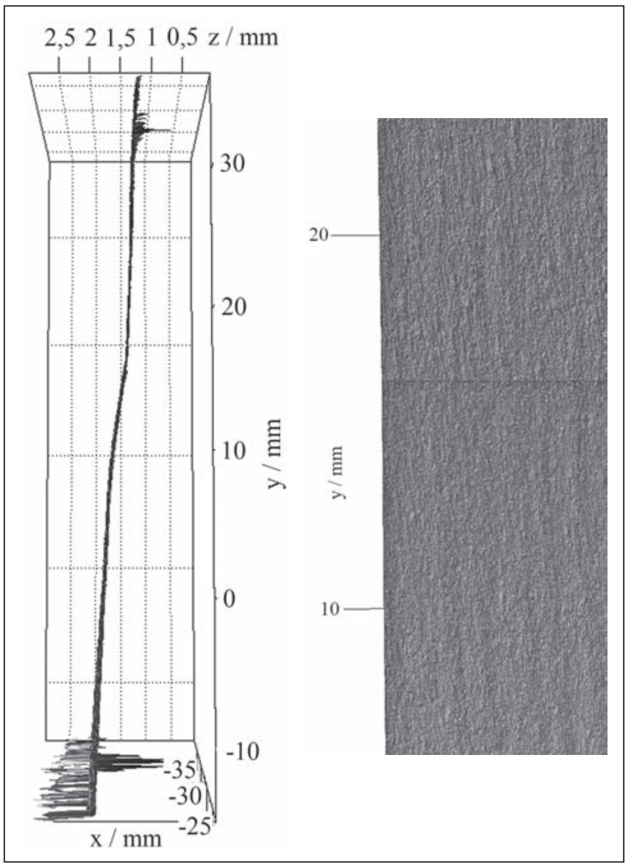

Figure 5 Surfaces created by abrasive waterjet, measured by non-contact optical method (Sample I)

recorded. Further increase of amplitudes was recorded around the frequencies of 6 500 Hz and 8 500 Hz. In the second cutting in the Figure 3 II sample the peaks were set out in a different way. A significant peak occurs around the frequency of 800 Hz. The peak of the FFT spectrum attributed to the stainless steel plate occurs around the frequency of 2 100 Hz. This peak does not occur in the spectrum of Al alloy. Other peaks might be observed on both spectra on the same frequencies around 5 000 Hz and 9 000 Hz. The cutting material topography is considerably different in the case of changed orientation. Lateral profile of the generated surface is shown in the Figure 4. The first part of the Figure 4, I sample illustrates the surface profile generated in a workpiece cutting with the upwards orientation of the Al alloy plate.

In the cutting of upper material part with a lower modulus of elasticity so-called undercutting occurs (Figure 5).

Having passed into the stainless steel the profile showed a formed jutting-out which consequently, under the influence of loss of kinetic energy and instrument integrity, slumped into the aforementioned undercutting as in the upper part. With the opposite orientation shown in the Figure 4 II, sample, in the case of which the stainless steel plate was turned upwards, the characteristic V profile was recorded. After passing into the material with lower modulus of elasticity the undercutting caused by the aforementioned loss of kinetic energy and instrument integrity was again recorded. The passing zone between both materials was the most obvious on the first cutting profile. After impact upon another material layer the instrument had to exceed the increased value of modulus of elasticity and the mechanism of topography generation was to be realized anew with the degraded instrument. In the case of the profile of the second cutting the zone appeared in the waved part of the generated surface. Since in this event the instrument passed form the material with higher modulus of elasticity to the material with lower modulus, the AWJ energy loss occurred.

CONCLUSIONS

The study deals with the examination of cutting of inhomogeneous sandwich materials by means of vibration emission of the cutting material. A cutting workpiece was composed of metal plates made of diverse materials of different moduli of elasticity. Material undercutting occurs in the case of material with lower modulus of elasticity. After moving out of the focusing tube the instrument tends to expand and dissipate into the surroundings. Material with low modulus of elasticity is not capable of sufficient resistance and generates a negative to the expanded instrument shape. When the instrument had passed into the material with higher modulus of elasticity in upward workpiece orientation by means of aluminium alloy plate the mechanism of the surface generation was realized anew with the instrument which lost part of its initial energy. Cutting of sandwich materials represents a big challenge for any conventional or unconventional technology. In the case of such materials each technology disposes of own typical problems and drawbacks. One of drawbacks of the abrasive waterjet cutting technology is a possibility of instant cutting process control.

Acknowledgements

The work has been supported by project VEGA 1/0972/11.

REFERENCES

[1] T. Sano, M. Takahashi, Y. Murakoshi, S. Suto, K. Matsuno, Abrasive water-jet cutting of amorphous alloys, In: Journal of Materials Processing Technology, 1992., pp. 571-583

[2] J. Zeng, T.J. Kim: An erosion model of polycrystalline ceramics in abrasive waterjet cutting, In: Wear, 1996., pp. 207-217

[3] J. Wang, W.C.K. Wong, A study of abrasive waterjet cutting of metallic coated sheet steels, In: International Journal of Machine Tools & Manufacture, 1999., pp. 855-780

[4] E. Lemma, L. Chen, E. Siores, J. Wang, Study of cutting fiber-reinforced composites by using abrasive water-jet with cutting head oscillation, In: Composite Structures, 2002., pp. 297-303

[5] M.A. Azmir, A.K. Ahsan,: Investigation on glass/epoxy composite surfaces machined by abrasive water jet machining, In: Journal of Materials Processing Technology, 2009, pp. 122-128

[6] V. Peržel, P. Hreha, S. Hloch, et al. Vibration emission as a potential source of information for abrasive waterjet quality process control. International Journal of Advanced Manufacturing Technology, 2012., pp. 285-294

[7] P. Hreha, S. Hloch, V. Peržel, Analysis of acoustic emission recorded during monitoring of abrasive waterjet cutting of stainless steel AISI 309. Tehnicki Vjesnik-Technical Gazette, 2012., pp. 355-359

[8] A. Stoić, M. Duspara, B. Kosec, M. Stoić, I. Samardžić. Application of water jet for cutting polymer materials, Metalurgija52(2013)2, 255-258.

Note: Responsible translator: Željka Rosandić, Faculty of Mechanical Engineering in Slavonski Brod, University of Osijek, Slavonski Brod, Croatia