12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

LASER CUTTING VS. MILLING FOR HOBBY PURPOSE

Martina Malachová
Brno University of Technology, Department of Mechanical Engineering
Technická 2896/2, 616 69 Brno
Czech Republic

Ondřej Bílek
Tomas Bata University in Zlín, Department of Production Engineering
Mostní 5139, 760 05 Zlín
Czech Republic

ABSTRACT
The aim of this paper was to choose appropriate technology for machining of individual parts used in aeromodelling. Balsa was used as an engineering material. The most often used machining technologies were laser machining and machining with use of CNC milling machine. Firstly, experimental results were preset for chosen entry condition. Secondly, visual evaluation of machined surface was done.
Keywords: Milling, Laser Machining, Aero-Modelling, Balsa, Cutting Condition

1. INTRODUCTION
Engineering materials are materials that are used for a creation of individual parts of a model aeroplane. Balsa is used for the ribs of the wings, spruce for the beams of the wings, steel for connecting wires of the wings and for an undercarriage, and polyethylene for a cockpit. The models aeroplanes are mostly fully made of balsa and that is why balsa was used for the creation of the testing sample. Harder and heavier materials are often used only for specially strained parts (compare in Tab.1). Concerning aeromodelling, balsa has remained the most frequently used material. It was firstly applied in 1920. Nowadays, big aeroplanes are also made of balsa.. A laser and a milling machine are most frequently used technologies for machining of balsa. In case of the laser, cutting condition is chosen according to thickness of the given material with the aim of minimization of a cutting time. Laser machining ensures sufficient surface quality without any additional treatment of the surface. On the other hand, a change of colour of an area of cut, caused by burning of the material at this place, can be sometimes considered as a disadvantage. Milling of balsa is used only if the thickness of the material is sufficient (bigger) and a surface quality after machining is not a predominant factor. Typical cutting tools – mostly with one blade – are used for machining. Cutting condition is chosen with the aim of reduction of burrs and imperfection of the cutting surface.

Table 1: Properties of balsa in comparison to other materials

Material	Density [kg/m^3]	Buckling Strength [%]	Bending Strength [%]	Compression Strength [%]
Balsa	160	100	100	100
Linden	420	261	288	288
Spruce	450	230	260	289
Walnut	590	301	506	512
Oak	770	295	430	366

2. EXPERIMENTAL PART

2.1. Experimental Milling

HWT milling machine is CNC milling machine for milling of soft materials, such as wood, plastics and non-ferrous metals. Machining is controlled by a computer according to NC programme. There must be sufficient clamping force when milling of profiles made of balsa or plywood boards. It is also necessary to ensure complete cut of a board with minimal destruction of clamping device surface. A grid of beams was screwed to an upper board to prevent this negative effect. The grid consisted of spruce beams with dimensions of 10 x 10 x 380 mm that were regularly arranged. As a result, boards were sufficiently hold and did not bend during milling. In case of their wear, they can be easily changed without dismantling of an appliance. Next, machined boards are attached to the beams by pins ensuring sufficient clamping force with regard to the shift of the machine – Fig. 1.

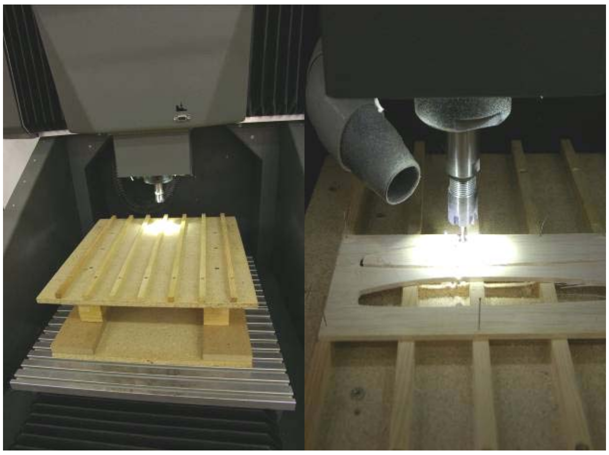

Figure 1. Clamping appliance of HWT C-442 CNC Profi milling machine

2.2. Experimental Laser Machining

Samples for laser machining were made of the same material and with the same dimensions as in case of milling. Machining strategy was designed in GravoStyle G5 programme in which intensity of laser and shift speed were set. Next these data were transferred into the machine. Similar to milling, it is possible to design a product in one computer and transfer it into the computer of the controlling machine through memory card. On the other hand, it can also be designed just in the computer of the controlling machine. The pyramids shaped in a lathe were placed on work area of the machine. They hold the boards to prevent wear of work area of the machine. Balsa boards were placed on the pyramids. Firstly, a laser head gets above the surface of the material, focuses and returns to a zero point where it waits for manual start of the programme.

Figure 2. Placement of balsa board on a Laser LS700 30W

Milled samples were compared with samples machined by Laser LS700 30W. It is a compact machine for labelling, gravitation and cutting of non-ferrous materials, such as plastics, wood, acrylate, polished metals, glass and leather, etc. The machine equipped with CO_2 laser engraving machine with wavelength of 10,6 μm and capacity of 30 W is able to label souvenirs, landmarks, cups, trophies, and produce wooden and paper decoration, labels made of plastics and satin anodized aluminium, it is also able to mark bottles and glasses. Dimensions of the machine are 760 x 440 x 725 mm and weight is 43 kg. Work area is 460 x 305 mm, marked thing can be maximal 147 mm. It is also easy to prepare graphic by PC in raster or vector mode. It allows usage of GravoStyle G5, CorelDRAW and other graphical programmes.

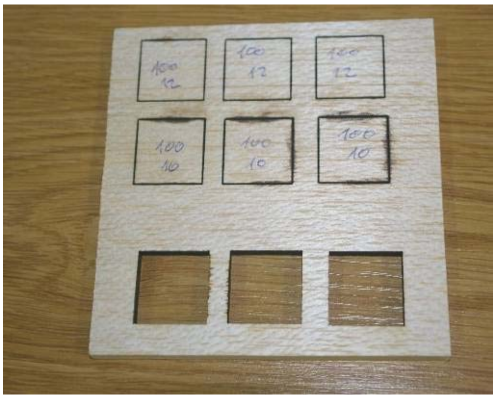

Figure 3. Final samples machined by laser

2.3. Production Method and Description of the Sample

The sample is a square 20 x 20 mm, its thicknesses are 5 mm and 6 mm. Fig.3 Its shape and arrangement was designed in AutoCAD 2002 programme and transferred into SurfCAM programme that furthermore generates path of the tool based on our demands (tool type, shift speed, chip depth, etc.). This path is used by controlling system of the milling machine. This method allows fine-tuning of the controlling programme with help of a simulation of machining when tool's movement can be visible on the screen. Simulation pre-empts collision and possible destruction of the tool or clamping device.

Tool types and cutting condition were changed during milling. Several samples were created in one working cycle in different technological conditions (Table 2). Used cutters differentiated by their type, diameter and number of edges (Tab.3).

Laser machining of the same samples was done by Laser LS700 30W, laser intensity and shift speed were changed. Balsa material with thicknesses of 5 and 6 mm was used as the sample. Experimental conditions for laser machining are presented in Tab. 4.

Table 2. Technological condition when milling by HWT C-442 CNC Profi

Sample Number	Material Thickness	Revolution [1/min]	Feed [mm/min]	Diameter of Cutter [mm]	Number of Cutting Edges	Chip Depth [mm]
1	6	20000	400	3	2	3
2	6	20000	800	3	2	3
3	6	15000	800	3	2	3
4	5	20000	400	3	2	5
5	5	20000	400	3	2	2,5
6	5	20000	800	3	2	2,5
7	5	20000	400	3	1	2,5
8	5	20000	800	3	1	2,5
9	6	20000	400	3	1	3
10	6	20000	800	3	1	3
11	6	20000	400	2	3	3
12	6	20000	800	2	3	3
13	5	20000	400	2	3	2,5
14	5	20000	800	2	3	2,5

Table 3. Identification of the samples for milling

Tool Description	Tool Definition
Tool Type 1:	cutter, Ø 3 mm, 1 edge
Tool Type 2:	cutter, Ø 3 mm, 2 edges
Tool Type 3:	cutter, Ø 2 mm, 3 edges

Table 4. Conditions for laser machining

Sample Description	Conditions
Type1	laser intensity 90; shift speed 12 mm/s
Type 2	laser intensity 100; shift speed 9 mm/s
Type 3	laser intensity 100; shift speed 12 mm/s
Type 3	laser intensity 100; shift speed 15 mm/s

3. RESULTS

Surface roughness was evaluated by Mitutoyo SJ-301 device. Measurement was done on 0,8 mm track by shift speed of sensor 0,5 mm/s, λ_c = 0,8 mm. A device did three measurements on track of 0,8 mm and final Ra and Rz values are average values of these measurements. Profile curve was also done. The sample was measured throughout its circumference, i.e. twice in fibre direction and twice in direction perpendicular to fibres. It was always perpendicular to tool movement. Three samples were produced in the same conditions.

3.1. Milling

Final roughness in direction parallel with fibres were: Ra = 1,75 ± 1,01 µm, Rz 8,91 ± 5,46 µm for sample with thickness of 6 mm after machining by cutter Ø 3mm with shift of 400 mm/min.

Final surface roughness of area perpendicular to fibres were: Ra = 6,51 ± 1,88 µm a Rz = 35,80 ± 10,56 µm. The roughness differs with the change of shift speed to 800 mm/min and at the same sample thickness – Ra =4,32 ± 1,56 µm. Rz was also different - 25,99 ± 11,61 µm. On the other hand, roughness Ra in direction perpendicular to fibres is similar to above measurement with slower shift -

Ra 6,73 ± 1,08 μm. To sum up, it is better to use faster shift speed for single-edge cutting tool because 4 μm roughnesses is better than 2 μm concerning adhesive cohesiveness. Production itself is also more profitable. Roughness Ra of the sample with thickness 5 mm worsen in all direction on an average by 1 μm in the same condition.
Final roughness for two-edge cutting tool Ø 3mm, with shift 400 mm/min and sample thickness 6 mm were: longitudinal way - Ra 2,68 ± 1,53 μm, lateral - 10,99 ± 3,81 μm. Shift speed 800 mm/min: longitudinal way - 2,22 ± 0,79 μm, lateral - 10,99 ± 3,81 μm. It is considerable difference between longitudinal and lateral roughness. There was slight improvement for sample with thickness 5 mm but longitudinal and lateral roughness still differed about more than 4,5 μm.
Furthermore, three-edge cutting tool Ø 2 mm was used. Measured values of roughness were similar to values of the sample with thickness 6 mm machined by single-edge cutting tool. Roughness in longitudinal way is worse of 0,13 μm, there is improvement or Ra in lateral way of 2,3 μm. Smaller diameter of the cutter must be taken into account. To sum up, it is recommended to use it for machining of balsa to thickness of 3 mm.

3.2. Laser Machining

Values of Ra roughness of samples machined by laser are in interval from 2,96 ± 0,59 μm to 3,71 ± 0,74 μm in longitudinal way and 5,71 ± 1,04 μm do 9,92 ± 1,04 μm in lateral way. These values approaches values measured for samples machined by single-edge cutter tool. Comparing shift speed and purity of machined surface, milling machined does not gain advantages of laser. It is a reason why producers of model aeroplanes prefer laser technology.

4. CONCLUSION

Casting finish was observed by microscope in direction perpendicular and parallel to fibres. Samples machined by NC milling have frayed boundaries in direction of fibres. It is caused by tearing of the material during cutting. These frays must be removed by fine re-grinding by sandpaper before further processing of the sample (e.g. gluing, coating).
Samples produced by laser cutting do not have this problem. Their cutting plane is smooth without frays. On the other hand, it is burned by laser beam into brown or black colour. Vessels are also visible by microscope. Glue leaks into them and increases cohesiveness of glued joint.

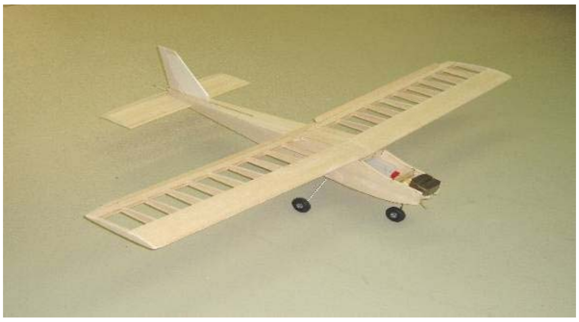

Figure 4. Final assembled part

Producers of the milling machines claim that it is better to use single-edge milling tools for machining of soft materials. Above mentioned results proved this fact. Aerial modellers prefer laser machining of the plane profiles because of the high quality of the final surface. The final assembled model of the aeroplane can be seen on the fig. 4.

5. REFERENCES

[1] BÁTORA, B., VASILKO, K. Hodnotiace kritéria drsnosti povrchov. Obrobené povrchy, technologická dědičnosť, funkčnosť. Nitra, GC Tech, 2000
[2] ČÍHAL, M. Výroba složitých výrobků pomocí NC stroje. Zlín, 2007. Bc na FT UTB Zlín.
[3] KOCMAN, K., PROKOP, J. Technologie obrábění. CERM, Brno, 2005. ISBN 80-214-3068-0.
[4] LUKOVICS, I., MALACHOVÁ, M. Use of Laser in Engineering. Manufacturing Technology, 2007 , roč. 7 , č. 7 , s. 6-10 , ISSN 1213248-8.
[5] SÝKOROVÁ, L., SHEJBALOVÁ, D. The Evalution Character of the Laser Emission. Acta Mechanica Slovaca, 2B/2006 PRO-TECH-MA r. 10., p. 417-422, Košice. SK, ISSN 1335-2393
[6] SÝKOROVÁ, L. Cutting Depth Determination within CO_2 Laser Micromachining. In: The 17th International DAAAM SYMPOSIUM, 8-11th November 2006,p.405-406,Vienna, Austria, ISBN 3-901509-57-7, ISSN 1726-9679