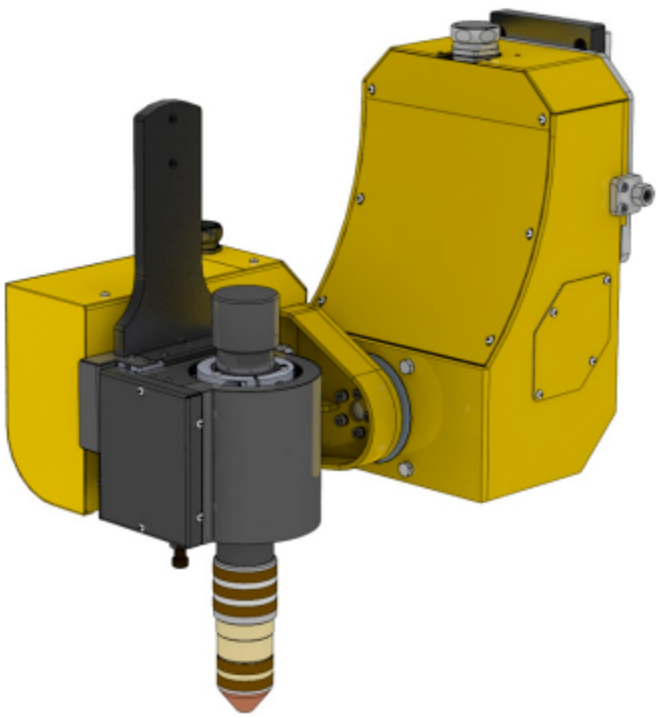
“3D bevelling tool station for MasterCut”

3D tilting plasma tool station enables bevel cutting with possibility of tilting up to 90º. The tilting head is designated to be attached to the universal cutting head of MasterCut machine. Plasma torch is fixed in the ITH anti-collision holder similarly manufactured and with the same IHS functions as in the case of R5 rotator type used on machines MG, DRM and CombiCut.

The initial height sensing is done mechanically or can be made by Ohmic contact. During cutting the distance between the torch and the plate is kept constant by means of measuring and controlling the plasma arc voltage (via servo motor in Z-axis, which gives the torch support the necessary dynamic). Fast and reliable torch height control results in high quality of cutting and long service life of consumables. Moreover, the torch is mounted into a protective holder, which guarantees the power to be switched off in case of torch collision, thus reducing the machine downtime caused by repairs.

The 3D beveling tool station has to be equipped with calibration station ACTG.



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Technical parameters:	
Width of tool station	350 mm
Max. material thickness	by plasma type
Stroke	150 mm
Weight of unit	40 kg
Position speed in Z	0-6 m/min
Position speed in Y	0-20 m/min
Torch inclination	+- 50°
Angular velocity in A axis	0-130 °/s
Angular velocity in B axis	0-130 °/s
Precision of cutting	ISO norm 9013:2002 tolerance class 2

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Limitations of kinematics chain

Minimum radius

Structure of the kinematic chain demands on machine speed dramatically increases in cutting arcs with small radii. For example, the support bearing the tool has to move at a 20-times higher speed than the cutting speed when the arc with the radius of 1 mm and bevel angle 50° is cut. At the common cutting speed of 2,000 mm/min it represents the machine speed of 40,000 m/min approaching the limit of plasma cutting machines.

For MasterCut machines, it is necessary to respect limitations of cutting speed to the value v_{max} = 10,000 mm/min. Of course, MasterCut machine can move faster but at higher speeds position following error affecting the overall shape accuracy of cut parts increases.

In arc bevel cutting, two cases can be distinguished – *undercutting and overcutting.* In case of undercutting (Figure 1), radius of the upper side of the cut component is a limiting factor.

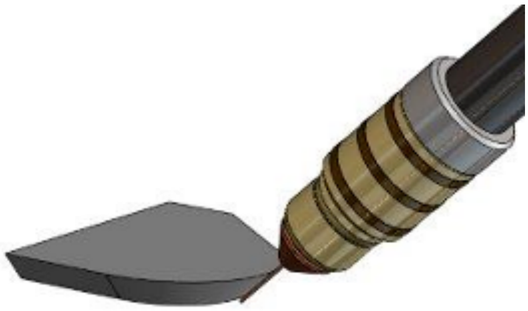

Figure 1 Undercutting (bottom bevel)

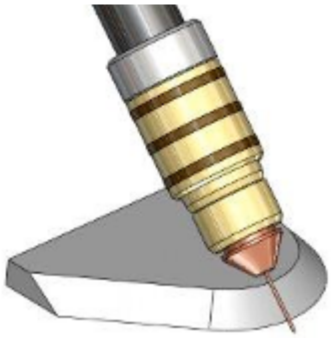

Figure 2 Overcutting (top bevel)

In case of overcutting (Figure 2), the limiting factor is the radius of the *bottom* edge of the component. This case differs from undercutting in the distance of the point which has to move at the speed v_r from the point of torch rotation not being L but $L + h / \cos \alpha$ (h is thickness of cut material)

Undercutting

Graphical plot of minimum radius r_{1min} versus cutting speed v_r for various values of bevel α is shown in following chart.

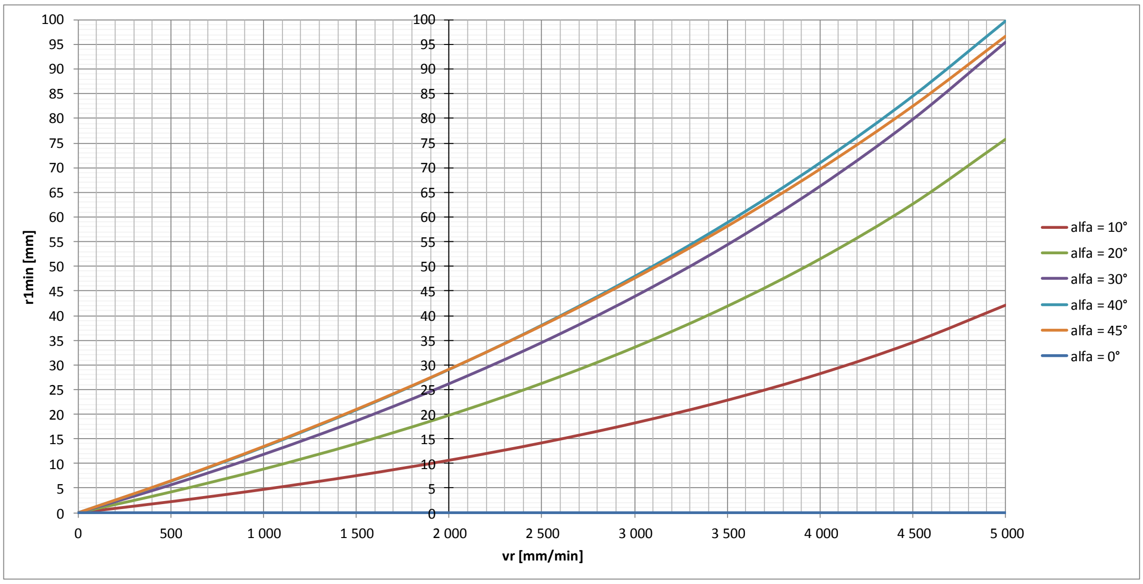

Figure 3 Dependence of minimal radius on cutting speed for various values of α angle (Undercutting)

Undercutting with given cutting speed can be applied for arcs with radius value situated above the line for respective bevel angle. For example with MasterCut machine it is possible to perform undercutting at speed 2,000 mm/min under angle (Figure 3):

45° arcs with radius greater than 29.1 mm

40° arcs with radius greater than 29.1 mm

30° arcs with radius greater than 26.2 mm

20° arcs with radius greater than 19.8 mm

10° arcs with radius greater than 10.7 mm

Over-cutting

Graphical plot of minimum radius r_{1min} versus cutting speed v_r for various values of bevel α is shown in following chart. The minimum radius of cutting depends on thickness of cut material.

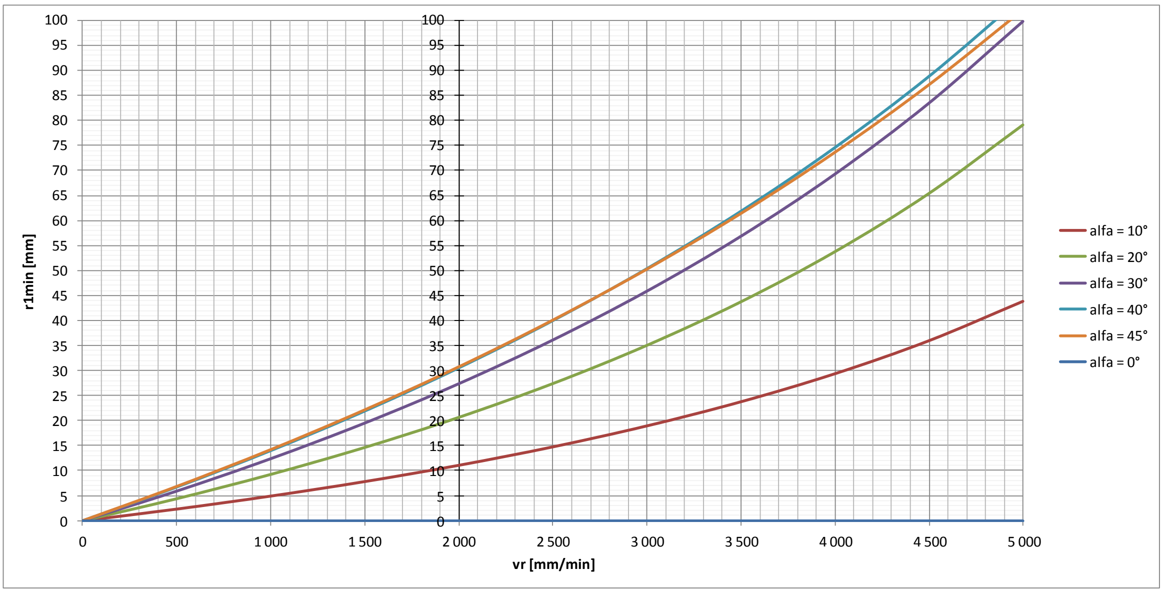

Figure 4 Dependence of minimal radius on cutting speed for various values of α angle (Overcutting, 10mm material thickness).

For calculation of minimum radius for various type of cutting and thicknesses please use following file.

Minimum radius for 3D tilting.xlsx

(In case the link is not functional follow file "Minimum radius for 3D tilting")

The machine can cut smaller diameters like are calculated above but the speed of movement of tip of the torch will slower.

Remark: *Presented results concern arc radius, diameter is doubled radius.*

Impact of gear train backlash (A and B motion axes)

Another significant source of inaccuracy in the use of the cutting head is sensitivity to the backlash of gear train of motion axes A and B.

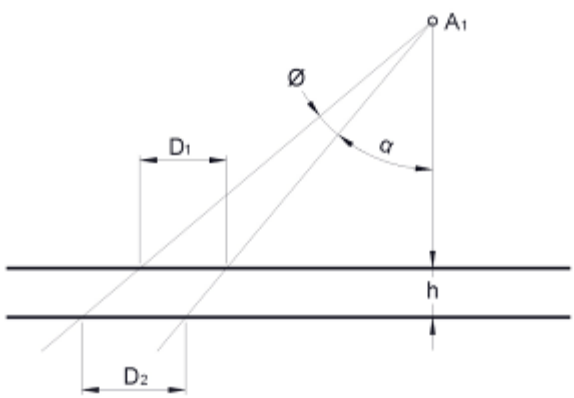

Figure 5 Impact of the A axis backlash of on the offset of cutting contour

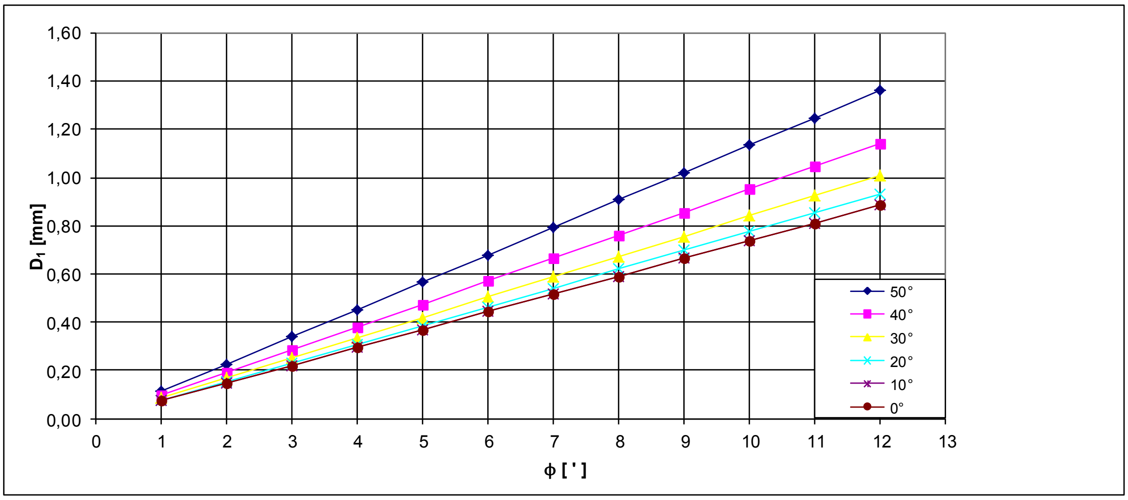

Figure 6 Dependence of the deviation D_1 on the angle ϕ representing backlash for *L = 250 mm* and various angles α

The graph demonstrates that backlash is mostly present in bevel cutting; inaccuracy is directly proportional to the bevel angle. For example, when the deviation of the torch is 0.1° (i.e. 6´) and the tilt of the torch is 50°, deviation in dimension of the component is approximately 0.7 mm. That means that the system is enormously sensitive to accurate setting of the position of the torch in the holder.

Inaccuracy in the setting of the torch in the holder, or inaccuracy of the return of the torch into the correct position after elimination of collision with the cut material, has similar negative impact on accuracy of the machine as backlash.

Inaccuracies of the whole kinematic chain of the machine also contribute to the overall inaccuracy of the cut parts.

Despite this fact, for price-sensitive applications the solution with tilting head makes sense to be offered because under certain limitations it can satisfactorily meet customer's needs. However, **it is necessary to clearly inform customers about limitations of the applicability.**

Increasing cutting accuracy

Aforementioned parts showed that the system with a tilting head is exceptionally sensitive to precise adjustment. The torch after collision needs to resume the correct position very precisely and this position must be also precisely adjusted. In operating conditions of a customer, precise adjustment of such kinematic chain is very important. It requires qualified operator with strong 3D imagination.

The problem of adjustment is eliminated by automatic calibration of the mechanism through the application of ACTG system. This system facilitates measurement of the position of the end point of the torch in the entirety of its orientation. Values measured by the controlling system are then compared with required values and based on this comparison the control system generates a table of correction values which are applied to modify output of the interpolator (generator of reference motion trajectories) for individual motion axis of the machine.

Exact return of the torch to the correct position after collision is secured also by a special construction of the torch holder ITH.

Backlash of the tilting head is minimized by the application of a special right angle hypoid gearbox with backlash below 3'. The impact of the backlash is compensated by the system ACTG. The backlash is partly compensated also because centres of gravity of rotating parts are located outside the rotation axis in the full range of motion.