APPLICATION SUITABILITY OF POWER-JET CUTTING TECHNOLOGIES FOR CONSTRUCTIONAL STEEL

MICHAL HATALA¹

Abstract: Production volume of welded structures of different types in Slovak plants, destined for foreign customers has increased. Modern methods of laser, water jet and plasma cutting of materials are discussed. The technical and economical characteristics of material cutting with these methods are mutually compared. Also some qualitative properties of cut components and type and range of processible semi products were compared; the cost for 1 hour labor on laser, water jet and plasma cutting equipment and the cost for effective of equipment work in dependence on investment costs and equipment utilization.

Key words: Laser, Water Jet, Plasma

1. INTRODUCTION

Nowadays there is swift improvement notable in the field of material cutting by concentrated sources of energy – jet technologies. Here belong the systems of cutting with laser, plasma, water jet. Improvement catches very sources as well as field of CNC control and machines which implement these technologies. It can be said that every jet technology has its typical application area, which is unreachable by other technology, and reach area of particular technologies (cut material type, cut thickness extent, cut surface quality, cutting gap width). Application areas of plasma, laser and water-jet technologies are relatively firmly set. For closer description of these technologies their basic advantages and disadvantages are presented.

1.1. Advantages and disadvantages of water-jet material cutting

Advantages:
- possibility of multi-component material cutting;
- complicated two or three-dimensional cuts, shape miscellaneousness;

¹ Faculty of Manufacturing Technologies TU Košice with the seat in Prešov, Štúrova 31, 080 01 Prešov, Slovak Republic, hatala.michal@fvt.sk
Advantages:

- no thermal impacted zone;
- cut edges without deformation;
- no overall stress;
- uncorrupted metallurgical structure of material;
- cut edge has higher strength as the result of deformation hardening with abradant;
- no steams or gases ensuing;

Disadvantages:

- low cutting speed;
- oxidation and corrosion of cut surface of iron materials;
- surface adjustment necessity;
- higher workplace moisture;

1.2. Advantages and disadvantages of plasma arc material cutting

Advantages:

- better cut quality when cutting thick materials (compare to flame cutting);
- cheaper than laser for cutting of thin sheets;
- low impact of working environment;
- suitable for thicker sheets with medium demand on cut edge quality and correctness;
- high cutting speed (depends on material thickness);
- possibility of reaching good surface roughness for steels and anticorrosion steels;
- simple replacement of throat, electrode, torch;
- relatively wide thickness extent of cut materials;

Disadvantages:

- noise level raises with raising of current;
- cannot create neither little rounds of cut edge nor strait grooves;
- serious cut width;
- different cut quality (bad side gets to waste);
- harmful steams ensuing (exhausting needed);
1.3. Advantages and disadvantages of laser material cutting

Advantages:
- possibility of cutting large contours as well as tiny and fine contours;
- thin cut gap which can be kept constant;
- high cutting speed;
- minimal cut surface quality, no additional surface treatment necessary;
- no need of changing the tool – no downtimes;
- minimum waste;
- chance to impact cut quality with additional cutting gas;
- relatively simple operation;
- very low thermal impacted zone.

Disadvantages:
- expensive laser devices (15…20 mil. Sk);
- necessity of special armatures (two-stage with metal membrane);
- very fine gases need.

2. EXPERIMENT PROPOSAL

For comparison of steel sheets cutting technologies, samples were cut with dimensions of 80×80 mm. Steel sheets ISO Fe510 with thicknesses 8 mm, 12 mm and 15 mm were used. Automatic settings of devices were used, which means that control system has chosen settings according to cut material parameters (material type and thickness). During the laser, water-jet and plasma arc cutting there were manufacturing times of each sample recorded together with feed and tools parameters.

In the cutting area is created material roughness which depends on feed speed of laser ray, water-jet or plasma arc. Quality of cut surface is also affected by several parameters of machine settings, components used, cut material quality. As the cutting torch feed speed raises, cutting arc (jet) is tailed behind. As a result roughness changes from the lowest value (upper surface) up to the highest value (lowest surface) as can be seen from recorded numbers.

3. TECHNICAL-QUALITATIVE COMPARISON

To the most important technical-qualitative characteristics in jet technologies of material cutting belong:
- cut quality, cut shape and width, maximum cut thickness possible, material divisibility – characteristics depending on cutting method and
material
  - thermal impact to the material – characteristic depending on used method and cutting parameters
  - dimensional and angular tolerances of cut components (as an entire unit) and weld surfaces
  - cutting device flexibility, device programming, shape cutting possibility

Achieved speeds and times were compared (Tab. 1) as well as cut edge quality (Tab. 2), where roughness was taken for main criteria.

Table 1. Comparison of speeds depending on cutting head feed

<table>
<thead>
<tr>
<th>Sample thickness, mm</th>
<th>Laser</th>
<th>Water-jet</th>
<th>Plasma arc</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>2,20</td>
<td>0,17</td>
<td>2,70</td>
</tr>
<tr>
<td>12</td>
<td>1,50</td>
<td>0,12</td>
<td>1,75</td>
</tr>
<tr>
<td>15</td>
<td>1,10</td>
<td>0,09</td>
<td>1,40</td>
</tr>
</tbody>
</table>

From this numbers results that the shortest times and therefore the highest speeds were achieved for single material thicknesses when cutting with plasma arc and laser. Slowest cutting was achieved with water-jet cutting where the speed was few-times slower than with other technologies.

Average roughness comparison of cut surfaces:

![Splitting of cut surface into the measured sections](image)

Fig. 4. Splitting of cut surface into the measured sections

From the measured roughness values the average roughness was calculated for upper and lower surface - Rai for each sample. Roughness comparison is presented in Table 2.

Table 2. Average roughness value for upper and lower edge of each sample

<table>
<thead>
<tr>
<th>Sample thickness, mm</th>
<th>Average roughness – Rai, μm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laser</td>
</tr>
<tr>
<td>Upper edge</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>4,18</td>
</tr>
<tr>
<td>12</td>
<td>4,32</td>
</tr>
<tr>
<td>15</td>
<td>4,82</td>
</tr>
<tr>
<td>Lower edge</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>9,78</td>
</tr>
<tr>
<td>12</td>
<td>15,04</td>
</tr>
</tbody>
</table>
Few deductions can be made from measured and computed values. Similar to the previous cutting speed valuation, in this comparison of upper and lower surfaces roughness it is obvious that best quality cut surface was achieved with plasma arc technology.

For laser cutting it is obvious that watched roughness parameter Rai raises with raising the thickness of material. Raise of roughness value is well-marked on lower edge, when after thickness change from 8 mm to 15 mm roughness raised almost twice. It can be assumed that this increase according to thickness was caused by lower output of laser device. From this detections results that laser cutting of materials is more suitable for thinner materials.

When cutting with water-jet technology the quality of cut edge grows a little with increasing of material thickness, thus doesn’t reach the quality of plasma cutting. An interesting closure can be made if we compare average roughness values for upper and lower surface. The value for upper and lower surfaces is almost identical.

To laser cutting advantages belongs: highly precise shape cutting, tiny cutting gap and uprightness of cut edges. On the other side with plasma cutting there is relatively large area of thermal impact, it is impossible to achieve such a precise shapes as with laser cutting and cut edges has noticeable uprightness divergence. In spite all of this, from technical-qualitative comparison of these experiment results, that best choice for cutting the steel ISO Fe510 is plasma arc cutting. Yet an economical comparison should be taken in consideration beside the technical-qualitative one when choosing the right technology.

### 4. CONCLUSION

As all presented methods of material jet-cutting have their advantages, it is the choice of every company to which option it will incline, according to their specific conditions. When doing the choice, general strategy of the company needs to be taken in consideration together with existing or potential customer demands, shape and dimensional exactitude and production repeatability, manufacturing agenda orientation and consequential manufacturing (treatment) technologies.

Last but not least it is important to have a device maximally utilized. Plasma cutting method finds its better application in praxis while using an oxygen as plasma gas for steel with medium thickness. Laser cutting is reaching better use especially when cutting thinner sheets, Cr-Ni steels, aluminum and its alloys. There are two main advantages: high productivity and cutting accuracy with minimum thermal deformations. As for water-jet cutting there is an advantage of cutting wide spectrum of non-metal materials.

Progressive improvement and dimension reduction of cutting devices together with aid of computer machinery insure installation growing of these technologies into the manufacturing process.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>19.16</td>
<td>5.42</td>
<td>3.74</td>
</tr>
</tbody>
</table>
REFERENCES

[8]. ***, NORMS: STN EN 12584 Chyby rezov zhotovených kyslíkovým plameňovým rezaním, laserovým rezaním a plazmovým rezaním; Terminológia.