Abstract: The laser processing apparatus including a concave mirror (2.2) which directs a radiation beam (5) reflected by the surface of a workpiece (4) back onto the said workpiece (4) is characterized in that the concave surface (6) of the mirror (2.2) is a combination of different concave profiles (6, 6.2), preferably a sphere (6) and an ellipsoid (6.2). Favorable results are also obtained by applying a mirror (2.2) with a surface formed by combining the profiles (6, 6.2) of a paraboloid and/or an ellipsoid and/or a sphere. The shape of the mirror (2.2) is intended to help increase the efficiency of the laser-workpiece system and generate a secondary beam (5”), which is responsible for the formation of an absorptive layer. The amount of the secondary radiation beam (5”) can be regulated depending on the type of material to be treated.

Fig. 1
Laser processing apparatus

The present invention relates to a laser processing apparatus equipped with a mirror intended to increase the effective use of a laser beam. More specifically, the invention relates to the effective use of laser energy for heating and cutting various materials, preferably metals.

The applications of laser in engineering and manufacture involve considerable scattering of electromagnetic radiation, which leads to a decrease in the real power of a laser beam and a decrease in the efficiency and capacity of the laser-workpiece system. It is estimated that the proportion of laser energy scattered is significant. For some materials, it may reach 95%. To prevent this from happening, the surface of a workpiece to be treated is usually coated with an antireflective layer. As such coatings are capable of absorbing scattered energy, the laser effectiveness is enhanced. The method, however, is difficult to use; moreover, the layer may interact chemically or physically with the workpiece material, which is an undesirable phenomenon. The most effective are metal-oxide coatings, of which some may absorb up to 90% of laser energy.

The methods described in US Patent Applications Nos. 4288678A and 4665298A imply that the efficiency of laser processing can be enhanced by using a spherical mirror. A similar technique was described in Polish Patent Application No 306289. These inventions relate to apparatuses including a mirror whose surface is in the shape of a section of a sphere, which directs a radiation beam reflected by the surface of a workpiece back to a first focus point causing an increase in the material.
temperature. US Patent Application No 4665298A describes a mirror with a profile in the shape of an ellipsoid. The profile is generated by joining several flat mirrors together.

According to the present invention, the laser processing apparatus equipped with a concave mirror fixed to the laser generator, which directs a laser radiation beam reflected by the surface of a workpiece back onto the said workpiece, is characterised in that the surface of the mirror is a combination of concave profiles, preferably, those of a sphere and an ellipsoid.

The shape of the mirror surface contributes to an increase in the capacity of the laser-workpiece system, and the generation of a secondary beam, with the latter being responsible for the formation of an absorptive layer.

An alternative solution is that the concave surface of the mirror is a combination of a sphere and a paraboloid. In such a case, the radiation reaching the spherical part of the mirror is reflected back to the first focus point, while the radiation reaching the parabolic surface is reflected back to the workpiece surface causing an increase in its temperature.

Another solution is that the concave surface of the mirror is a combination of a paraboloid and an ellipsoid. The radiation beam reflected back by the parabolic part of the mirror heats the surface of the workpiece, while the radiation beam reflected by the ellipsoidal part constitutes a secondary beam.

In the next solution, the concave surface of the mirror is a combination of a sphere, a paraboloid and an ellipsoid, with the ellipsoidal surface being generated within the spherical part.

Still another solution is to employ a concave mirror with a surface generated by combining the profiles of a sphere, an ellipsoid and a paraboloid, with the ellipsoidal surface being formed within the parabolic surface. The shape of the mirror is intended to help increase the laser-workpiece system efficiency and generate a secondary beam. The amount of the secondary radiation beam can be regulated depending on the type of material to be treated.

The secondary beam generated during the reflection of scattered radiation is responsible for the formation of an absorptive oxide layer that is capable of absorbing up to 95% of the energy of the laser beam. It can also eliminate the necessity of depositing an antireflexive layer. By increasing the efficiency of the laser-workpiece system, it is possible to treat workpieces with larger dimensions or to reduce the
power of lasers or to increase their capacity. This allows effective alloying, metal remelting and more efficient heat treatment of metal and alloy surfaces.

The formation of a secondary beam may have a positive effect on the welding process. Many types of materials need to be preheated to a relatively high temperature before they are welded. A secondary beam makes it possible to obtain an appropriate temperature of the material to be treated without the need to apply other pre-heating methods, e.g. preheating in a furnace, preheating with a burner, etc. Applying a secondary radiation beam is a simple and cheap method for the preparation of material to be welded, e.g. structures with large dimensions such as sheet pile walls in boilers.

Hereinafter, the embodiments of the present invention will be described in detail with reference to the accompanying drawings; FIG. 1 shows schematically a laser radiation generator including a mirror whose concave surface is a combination of a sphere and an ellipsoid; FIG. 2 shows schematically a laser radiation generator including a mirror whose concave surface is a combination of a sphere and paraboloid; FIG. 3 shows schematically a laser radiation generator including a mirror whose concave surface is a combination of a paraboloid and an ellipsoid; FIG. 4 shows schematically a laser radiation generator including a mirror whose concave surface is a combination of a sphere, a paraboloid and an ellipsoid; FIG. 5 shows schematically a laser radiation generator including a mirror whose concave surface is a combination of a sphere, an ellipsoid and a paraboloid.

In the embodiment shown in FIG. 1, the concave mirror 2.2 mounted on the laser radiation generator 1 has a surface formed by combining a spherical profile 6 and an ellipsoidal profile 6.2. The laser generator 1 emits a radiation beam 3 that is focused onto a workpiece 4. A portion of the radiation 3 that is not absorbed by the said workpiece 4 travels to the mirror 2.2 as the beam 5. After reaching the spherical surface 6, the beam 5 is reflected back to the first focus point 9 on the workpiece 4 causing an increase in its temperature. The ellipsoidal surface 6.2. of the mirror 2.2 reflects the beam 5 back as the beam 5' to the first focus point 9 or as the beam 5L to the second focus point 9*, depending on the angle of incidence. The arrow 8 designates the direction of the laser beam relative to the workpiece 4.

Figure 2 illustrates an embodiment where the laser radiation generator 1 includes a concave mirror 2.3 whose surface is a combination of a parabolic profile 6.1 and a spherical profile 6. The laser generator 1 emits a radiation beam 3 that is
focused onto a workpiece 4. A portion of the radiation 3 that is not absorbed by the said workpiece 4 travels to the mirror Z3 as the beam 5. The parabolic surface 6.1 reflects the radiation beam 5 back to the first focus point 9. Part of the radiation is reflected perpendicular to the workpiece 4 as the beam 5 causing an increase in the workpiece temperature. The spherical surface 6 of the mirror Z3 causes that a portion of the beam 5 is reflected back to the first focus point 9.

As illustrated in FIG. 3, the laser radiation generator 1 includes a mirror 2.4 whose concave surface is a combination of a paraboloid 6.1 and an ellipsoid 6.2. The laser generator 1 emits a radiation beam 3 that is focused onto a workpiece 4. A portion of the radiation 3 that is not absorbed by the said workpiece 4 travels to the mirror 2A as beams designated as 5 and 5'. Depending on the angle of incidence, the radiation beam is reflected back to the focus point 9, or is reflected perpendicular to the workpiece 4 as the laser beam 5' causing an increase in its temperature. The ellipsoidal surface 6.2 of the mirror 2A causes that a portion of the beam is reflected as the beam 5" to the second focus point 9.

In the embodiment presented in FIG. 4, the concave surface of the mirror 2.5 is formed by combining the profiles of a sphere 6, a paraboloid 6J, and an ellipsoid 6.2, with the ellipsoidal surface 6.2 being generated within the spherical surface 6. The laser generator 1 emits a radiation beam 3 that is focused onto a workpiece 4. A portion of the radiation 3 that is not absorbed by the said workpiece 4 travels to the mirror 2.5 as the beam 5. Depending on the angle of incidence, it is then reflected from the spherical surface 6 and the ellipsoidal surface 6L2 of the mirror Z5 back to the first focus point 9 or as the secondary radiation beam 5' to the second focus point 9', causing an initial increase in the workpiece temperature leading to its oxidation. The parabolic surface 6.1 of the mirror Z5 redirects the beam 5 depending on the angle of incidence; it goes back to the first focus point 9 or is reflected perpendicular to the workpiece 4 as the beam 5' causing an increase in the workpiece temperature.

In the solution shown in FIG. 5, the concave surface of the mirror 2J3 is formed by combining the profiles of a sphere 6, an ellipsoid 6J2 and a paraboloid 6.1, with the ellipsoidal surface 6L2 being generated within the parabolic surface 6.1. The laser generator 1 emits a radiation beam 3 that is focused onto a workpiece 4. A portion of the radiation 3 that is not absorbed by the said workpiece 4 travels to the mirror 2.6 as the beam 5. Depending on the angle of incidence, it is then reflected from the parabolic surface 6.1 back to the first focus point 9 or as the beam 5' perpendicular
to the workpiece 4 causing an increase in its temperature. The ellipsoidal surface 6 of the mirror 2 redirects the beam depending on the angle of incidence; it goes back to the first focus point 9 or is reflected as the beam 5" to the second focus point 9' causing an initial increase in the temperature of the workpiece leading to its oxidation. The spherical surface 6 of the mirror 2 redirects the beam 5; it returns to the focus point 9 causing an increase in its temperature.

In each of the embodiments of the present invention, the laser generator moves in the direction designated as 8. For the solutions shown in FIGS. 1-3, the direction of the motion of the laser generator has no effect on the operation of the apparatus.
Claims

1. The laser processing apparatus including a concave mirror fixed to the laser radiation generator intended to direct a radiation beam reflected by the surface of a workpiece back onto the said workpiece is characterized in that the concave surface of the mirror is a combination of, preferably, a sphere /6/ and an ellipsoid /6.2/.

2. The apparatus, according to Claim 1, is characterised in that the concave surface of the mirror /Z3/ is a combination of a sphere /6/ and a paraboloid /6JL/.

3. The apparatus, according to Claim 1, is characterised in that the concave surface of the mirror /Z4/ is a combination of a paraboloid /6J/ and an ellipsoid /6.2/.

4. The apparatus, according to Claim 1, is characterised in that the concave surface of the mirror /Z5/ is a combination of a sphere /6/, a paraboloid /6.1/ and an ellipsoid 1621, with the ellipsoidal surface IQ2J being generated within the sphere /6/.

5. The apparatus, according to Claim 1, is characterised in that the concave surface of the mirror /Z6/ is a combination of a sphere /6/ an ellipsoid IQ2J and a paraboloid /6L/1, with the ellipsoidal surface /6,2/ being generated within the paraboloid /6.1/.

6
### A. CLASSIFICATION OF SUBJECT MATTER

INV. B23K26/06 B23K26/20 B23K26/42 B23K26/14 B23K26/00

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B23K G02B C03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US 5 824 023 A (R. R. ANDERSON) 20 October 1998 (1998-10-20) column 9, lines 27-48; figure 6</td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>2-5</td>
</tr>
<tr>
<td>X</td>
<td>US 6 392 978 B1 (A. SATO) 21 May 2002 (2002-05-21) column 15, lines 10-20; figure 6</td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>2-5</td>
</tr>
<tr>
<td>A</td>
<td>US 4 288 678 A (A. V. LA ROCCA) 8 September 1981 (1981-09-08) cited in the application * abstract; claims; figures 3-4</td>
<td>1-5</td>
</tr>
</tbody>
</table>

D Further documents are listed in the continuation of Box C

X See patent family annex

"A" Special categories of cited documents

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

30 August 2010

Date of mailing of the international search report

07/09/2010

Name and mailing address of the ISA:

European Patent Office, P B 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel (+31-70) 340-2040
Fax (+31-70) 340-3016

Authorized officer

Jeggy, Thierry
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CA 2234455 A1</td>
<td>17-04-1997</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 9713458 A1</td>
<td>17-04-1997</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR 2450660 A1</td>
<td>03-10-1980</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 2046801 A</td>
<td>19-11-1980</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IT 1119679 B</td>
<td>10-03-1986</td>
</tr>
</tbody>
</table>