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# PATENTS FOR METAL DEPOSITION



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# Patents for Metal Deposition

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## Summary

During the winter 2003/2004 a new research group MIA (Mechatronics in Industrial Applications) was formed at HTU (University of Trollhättan/Uddevalla). One of the primary research areas of the group is to develop an automatic robotised metal deposition.

Metal deposition is a method where a metal feature is built by adding welding material to create the wanted shape. A common way to build a part is to add material by powder or wire. The material is melted using a heat source, e.g. a tungsten electrode (TIG welding equipment) or laser. The idea of the method is to building up layers to create the wanted products or add metal features, like flanges, bosses and pads, to existing products.

As one of the first steps of the research a patent search have been conducted which aimed at finding patents for metal deposition and sensor system used to control the metal deposition process.

The search resulted in 17 patents where most of the patents can be classified into the more general type of patents and only two can be classified for control and sensor system.

During the search of patents the search had to be narrowed using more search words. The reason was that a search with “wide” and few words generated such amount of patents so it was impossible to look into the information.

From the patents found only a few covered the use of control and sensor system for metal deposition. One way of explaining this is that the research is just in the beginning and that the MIA group has found an area that still have much yet to develop.

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## **1 Introduction**

As one of the research groups active at the University of Trollhättan/Uddevalla (HTU), Sweden, is the MIA-group (Mechatronics in Industrial Applications), aims for research on controlling and supervision of industrial processes. The group was founded during the winter of 2003/2004 as a parallel and co-operating research group to the successful research group VIP (Verkstadsindustriprocesser), also at HTU.

At this point a couple of different projects have been undertaken by the research group among them the development of a sensor and control system for robotised metal deposition. Within this project many smaller areas are researched as starting points of the project, among them a patent search for metal deposition.

### **1.1 Background**

Metal deposition is a method where a metal feature is built by adding welding material to create the wanted shape. A common way to build a part is to add material by powder or wire. The material is melted using a heat source, e.g. a tungsten electrode (TIG welding equipment) or laser. The idea of the method is to building up layers to create the wanted products or add metal features, like flanges, bosses and pads, to existing products.

Some areas of interest for metal deposition are to build prototypes, adding features to parts and repairing damaged parts. The advantage of using metal deposition for building prototypes compared to the already available rapid prototyping (RP) and free form fabrication (FFF) methods is that the created part is in metal and therefore has the material properties of the finished part. This makes the method suitable for one of a kind production or small series. The ability to add features to a part gives possibilities to improve and import changes to old parts and also the possibility to use a simple and low cost base feature and adding advanced features by using metal deposition to generate a complex part.

The possibility to repair damage parts instead of discarding them can make a huge saving if the part is expensive, e.g. cast of titanium or stainless steel or tools.

### **1.2 Aim and objectives**

The main aim of this report is to present a short summary of patents that are of interest at this point of time for the metal deposition project conducted at the University of Trollhättan/Uddevalla.

The objectives of this report were:

- To describe technologies for metal deposition found in the patents
- To describe sensor systems for metal deposition found in the patents

### 1.3 Restrictions

This report only contains patents that seem relevant at this point of time for the metal deposition research conducted at the HTU. Neither evaluation nor tests of the patents presented in the report have been conducted. The information presented in the report has only been found in patents, no other source of information, such as technical papers, have been used.

### 1.4 Methodology

The information presented in this report is collected from patents found using the search page on the European Patent Office (EPO) website (<http://ep.espacenet.com/>). The EPO website was preferred to use over the US Patent website because of its more user-friendly search tool and that its search results contains patents from other patent organisations, e.g. Japanese, Swedish and English. For downloading and printing the US patent website (<http://www.uspto.gov/patft/index.html>) was preferred because its user-friendliness for the mentioned tasks. One problem is that non-American patents are not available on the web site so the European has to be used for them.

On the EPO web site the patents are available in for viewing and printing in PDF format. The US patent website uses a file format for the patents called TIFF and one of the suitable softwares is AlternatIFF and can be downloaded from <http://www.alternatiff.com/>.

The patent search was divided into two areas were the first one was a more general search for patents for metal deposition. The second search was focused on finding patents for sensor and control systems for metal deposition.

The search started of with

The first part of the search was conducted using the following key words:

1. *metal deposition* in title or abstract, 14,700 hits, too much information
2. *shape metal deposition* in title or abstract, 382 hits, no match with the subject
3. *deposit welding* in title or abstract, 472 hits, several matches, most of them with Jones Steven Alan as inventor
4. *Jones Steven Alan* as inventor, 77 hits, several new matches

Most of the matching patents had one thing in common, the classification B23K9/04, representing the class “welding for other purpose than joining, e.g. build-up welding”.

5. *B23K9/04* as European classification, 849 hits, several new matches

The second part of the search was conducted using the following key words:

1. *sensor metal deposition* in title or abstract, 588 hits, 1 match with the subject
2. *control metal deposition* in title or abstract, 111 hits, no match

Some of the patents have been found when being referenced to in the already found patents.

More information about the European classification, used in one of the searches, can be found in Appendix A.

## 2 Patents

The following patents have been taken into consideration and are described briefly in the following:

- **US6274839** also published as EP1005941
- **EP1245323** also published as US2002139778
- **EP1302269** also published as US2003127431
- **EP1245322** also published as US2002139780
- **US2002139779** also published as EP1245321
- **EP1354658** also published as US2003189028
- **EP0529816** also published as US5207371 and JP5192767
- **US5233150** also published as EP0496181 and JP4336304
- **US6143378**
- **US5578227** also published as WO9822253
- **US4323756**
- **EP1281467** also published as US2003024916
- **GB2372349**
- **US6122564** also published as WO0000921, EP1099184, CA2336583, RU2228243 and AU754346
- **US2002110649**

Most of the patents describe an invention that improves the build process for metal deposition. However two of the patents, US5233150 and US6122564, contain proposals for control systems to automate metal deposition.

### **2.1 Method and apparatus for building up a workpiece by deposit welding**

*Patent number:*           **US6274839**  
*Also published as:*       EP1005941  
*Publication date:*       2001-08-14  
*Inventor:*                 Stone, Kevin H and Pearce, Nigel P  
*Applicant:*               Rolls Royce Plc

This patent describes a method that allows off-line programming for metal deposition. It also claims the use of available software to create the tool path.

#### **Claim:**

A method of forming an article comprising the combination of steps:

- Creating a first data file containing the three dimensional model of the work piece in a computer memory or equivalent data storage.
- Executing a computer program that from the first data file creates a second data file that contains the co-ordinates describing a tool path through the three dimensional work piece.

- Exporting the path defined in the second data file to a multi-axis welding robot to build up the three dimensional work piece.
- The three-dimensional work piece is deconstructed (split into layers of deposition) by directing a computer representation of a tool within the algorithm to remove a succession of incremental volume portions from the work piece.
- Using a CAM system for the deconstruction of the work piece.
- Using a milling cutter to simulate the tool that increments the same amount of material that the weld head would deposit.

The patent also claims the use of a second data file that contains the movement and positions for the welding robot.

Another claim is to use a computer program that creates a third data file that contains the information in the second data file and adds user specified constraints about the robot movements and positions.

The claims are for a method where electric arc welding, metal inert gas (MIG) welding, tungsten inert gas (TIG) welding or laser welding head is used.

**Comment:**

The method of forming a workpiece in the patent is very similar to the method used to generate the welding path and simulation in the HTU thesis “MD banplanering och simulering”, 2004 by Mr Jonas Berg and Mr Jarmo Luukkonen.

## **2.2 Method and apparatus for building up a workpiece by deposit welding**

*Patent number:*        **EP1245323**  
*Also published as:*    US2002139778  
*Publication date:*    2002-10-02  
*Inventor:*             Jones, Steven Alan  
*Applicant:*            Rolls Royce Plc

This patent improves the possibility to a rapid change of build height and width generated by using multiple electrodes.

**Claim:**

To use two or more electrodes together when building a metal deposition work piece. This to make an easier, faster and greater shift in weld width possible.

Each electrode has its own control parameters for the possibility to have different values for wirefeed, current, voltage, distance to bottom plate and more.

To use different types of current for the individual electrodes (AC or DC) at the same time.

The electrodes can be angled towards each other to generate a narrower and higher weld bead form.

### **2.3 Apparatus and method for forming a body**

*Patent number:*           **EP1302269**  
*Also published as:*       US2003127431  
*Publication date:*       2003-04-16  
*Inventor:*                 Pratt, Anthony Lionel and Jones, Steven Alan  
*Applicant:*               Rolls Royce Plc

This patent improves the cooling of the work piece to allow different crystal structures to be created.

**Claim:**

Use cooled (-50°C or less) inert gas to cool the layed down seam or substrate to accomplish a more rapid transition of the material from one crystal structure to an alternative crystal structure.

By using two nozzles with turbulent flow of inert gas implies cooling in more than one spot of the layed down seam.

### **2.4 Method of forming a body by freeform welding**

*Patent number:*           **EP1245322**  
*Also published as:*       US2002139780  
*Publication date:*       2002-10-02  
*Inventor:*                 Jones, Steven Alan and Wright, Iain William  
*Applicant:*               Rolls Royce Plc

This patent is for changing the build height (thickness) during the deposition of the same layer by using predetermined changes of electric current, relative speed of the weld head and support and/or the supply of the weld material.

**Claim:**

A method of forming a body by deposition of weld material were the first portion has a predetermined thickness that is less than the predetermined thickness of the second portion.

Changes of the predetermined values of electric current, relative speed of the weld head and support and/or the supply of the weld material to change from a thinner layer of metal deposited to a thicker layer.

Changes of the predetermined values of electric current, relative speed of the weld head and support and/or the supply of the weld material to maintain the same thickness of the material deposited.

Building a taper between the first, thinner portion to the second, thicker portion by stepping values for electric current, relative speed of the weld head and support and/or the supply of the weld material.

**Comment:**

In the thesis “Development of Sensor System for Automated Metal Deposition”, 2004:RT03, HTU by Mr Jan-Erik Henriksson, Mr Simon Cronholm and Ms Jessica Jansson experiments where wire feed and current were altered during welding to analyse how the weld seam changed.

**2.5 Apparatus and method for forming a body**

*Patent number:* US2002139779  
*Also published as:* EP1245321  
*Publication date:* 2002-10-03  
*Inventor:* Jones, Steven A  
*Applicant:* Rolls Royce Plc

This patent is for using or building a frame for the part created and then building the part with the frame as sides of the part.

**Claim:**

To use a raised member on the support member to deposit the weld material to conduct heat from the created body during formation of the body.

To form a raised member on the support member using metal deposition before forming the wanted body, including forming the raised member in two sections.

The raised member can have wall shaped sides, tapered sides or one side tapered and the other wall shaped.

When two raised members are used they can have different shapes, orientations and cross-sections.

**2.6 Apparatus and method for forming a body**

*Patent number:* EP1354658  
*Also published as:* US2003189028  
*Publication date:* 2003-10-22  
*Inventor:* Wright, Iain William and Jones, Steven Allen  
*Applicant:* Rolls Royce Plc

This patent describes a method to build support geometries.

**Claim:**

By manipulating the weld head and support member relative to one another deposit material to form a first wall. Manipulations of the weld head and support member to deposit material to form a second wall extending from and angled to the first wall. Manipulating the weld head and support member relative to one another to deposit material between the first two walls, creating a third wall and completing a hollow section body.

Using a higher electric current when building the base and distal of the walls than for the middle parts of the walls to achieve broader ends of the walls than the middle section.

Keeping the support member about horizontal and the welding head about vertical when creating the first wall.

Tilting the support member when creating the second and third walls.

When creating the second and third wall the weld head starts in an almost vertical position but are angled as the walls are built.

The creation of other hollow section bodies consisting of four or more walls.

A method of creating a two or three dimensional model in a CAD and CAM software and from that model generate the path and coordinates needed for the weld head to create a robot program that builds the hollow model on an existing part.

## **2.7 Method and apparatus for fabrication of three-dimensional articles by weld deposition**

*Patent number:*       **EP0529816**

*Also published as:*   US5207371

                                  JP5192767

*Publication date:*    1993-03-03

*Inventor:*             Prinz, Fritz B and Weiss, Lee E

*Applicant:*            Prinz, Fritz B and Weiss, Lee E

This patent presents the use of a CNC machine for metal deposition. It also describes the use of complementary material for metal deposition and the use of milling tools on every layer that have been deposit.

### **Claim:**

A method to build a work piece by depositing material onto a work surface and even out the layers with complementary material along side the deposited material. This to allow the creation of geometries with tapered sides, where the bottom layer is smaller than the top layers.

To mill the deposited material to generate a more even surface before adding a new layer and/or to heat the material deposit to reduce thermal stress in the work piece.

Using a CNC machine equipped with:

- a welding head
- two different milling tools (one for straight milling and one for tapered)
- an induction heater and
- a head that supplies complementary material

for the metal deposition process.

## **2.8 Method of production of workpieces by welding equipment**

*Patent number:*           **US5233150**  
*Also published as:*    EP0496181  
                                  JP43336304  
*Publication date:*     1993-08-03  
*Inventor:*                Braun, Olivier; Dekumbis, Roger; Tanner, Bruno; Schneebeli, Fritz  
*Applicant:*              Sulzer AG

This patent presents a method for planning the tool path. Also a control system that levels out unevenness created in previous layers.

### **Claim:**

Using metal electrode inert gas (MIG) welding to create a new layer of deposited metal where the first step is to deposit the outline of the layer. Then weld material is deposited inside the outline to create the layer.

Sensing one of the welding parameters welding current or welding voltage to sense discontinuities in previously formed layers to make the control system to regulate parameters to generate a smoother surface.

To generate a workpiece consisting of at least one convexly curved section, and at least one concavely section and at least one section that connects the concavely and convexly sections.

### **Comment:**

The thesis “MD banplanering och simulering”, 2004 by Mr Jonas Berg and Mr Jarmo Luukkonen generates a weld track that for a cylindrical part starts to create the outside first before welding the rest of the layer in a helix shape. The difference from the matrix is that the thesis uses a “tune-in” phase, where welding parameters stabilises, inside the part before welding of the edges of the cylinder starts. Also the patent is for MIG welding while TIG welding was used in the thesis.

## **2.9 Energetic additive manufacturing process with feed wire**

*Patent number:*           **US6143378**  
*Publication date:*     2000-11-07  
*Inventor:*                Griffith, Michelle L; Greene, Donald L; Harwell, Lane D; Pressly Gary A  
*Applicant:*              Sandia Corp

This patent describes a method that allows creations of alloys in the melt-pool adding two different types of welding material.

### **Claim:**

Adding material to the melt-pool using at least two source wires with separate control wherein at least two of the source wires have substantially differing compositions thereby creating a part made out of an alloy.

## **2.10 Rapid prototyping system**

*Patent number:* US5578227  
*Also published as:* WO9822253  
*Publication date:* 1996-11-26  
*Inventor:* Rabinovich, Joshua E

This patent describes a method to create a work piece by welding or gluing small pieces of metal together.

### **Claim:**

A model building method comprising delivering thin, continuous feedstock of materials which have various profiles with opposite flat sides and fusing the feedstock by adhesion or welding a flat side with an energy source to a flat side of a previous layer, while keeping the feedstock cross-section in substantially original shape.

Varying the material deposited between metal and non-metal to create a composite material part.

## **2.11 Method for fabricating articles by sequential layer deposition**

*Patent number:* US4323756  
*Publication date:* 1982-04-06  
*Inventor:* Brown, Clyde O; Kear Bernard H; Breinan, Edward M  
*Applicant:* United Technologies Corp

This patent contains a method that builds a very thin layer using a lot of energy to avoid impurities and pores.

### **Claim:**

A method for producing metallic articles by using a starting substrate, which top surface is melted using sufficient energy and then adding material between the melted substrate and the energy beam. The layer created is very thin (not greater than 0.005 inches) but has very little impurities and also becomes pore free.

## **2.12 Apparatus and method for forming a body**

*Patent number:* EP1281467  
*Also published as:* US2003024916  
*Publication date:* 2003-02-05  
*Inventor:* Wright, Iain William and Jones, Steven Allen  
*Applicant:* Rolls Royce Plc

This patent describes a method on how to mix the materials in the weld-pool.

### **Claim:**

By applying a force, e.g. electro magnetic, the location of the weld pool is moved. During the move the material in the weld pool is mixed and a more uniform structure in the weld seam is obtained.

### **2.13 Apparatus and method for forming a body**

*Patent number:*       **GB2373749**  
*Publication date:*    2001-03-27  
*Inventor:*             Jones, Steven Allen  
*Applicant:*            Rolls Royce Plc

#### **Claim:**

Putting the apparatus for metal deposition in a chamber with an atmosphere that is substantially unreactive to weld material.

### **2.14 Fabrication of alloy variant structures using direct metal deposition**

*Patent number:*       **US6122564**  
*Also published as:*    WO0000921  
                              EP1099184  
                              CA2336583  
                              RU2228243  
                              AU754346  
*Publication date:*    2002-08-15  
*Inventor:*             Koch, Justin; Mazumder, Jyoti  
*Applicant:*            Koch, Justin; Mazumder, Jyoti

The patent describes a feedback control system containing an optoelectric sensor to determine the built height. The control system has an interface to a CAD/CAM system, which contains the model of the feature and the built feature is compared to the CAD/CAM model.

The patent also contains a comparison of a metal deposition product and a molded.

#### **Claim:**

This patent claims the use of an optoelectric sensor operative to output an electrical signal as a function of the height. The sensor is connected to a feedback control system that adjusts the deposition rate as a function of the electric signal.

The control system could use an interface to a CAD/CAM system with a model of the article to be fabricated and compares the built article to the CAD/CAM model

### **2.15 Fabrication of alloy variant structures using direct metal deposition**

*Patent number:*       **US2002110649**  
*Publication date:*    2002-08-15  
*Inventor:*             Skszek, Timothy W.; Lowney, Mathew T.J.; Morgan, Dwight  
*Applicant:*            Skszek, Timothy W.; Lowney, Mathew T.J.; Morgan, Dwight

This patent is a continuation of patent US6122564, but focuses on increasing lifetime of a tool by adding suitable alloys onto specially exposed areas.

**Claim:**

The patent describes the fabrication method where only a few parts of a tool is in-forced by first adding a high thermal or wear resistant layer using metal deposition. Then a second layer is, consisting of an alloy suitable for high strength or impact resistance, is added using metal deposition

### 3 Result

The search resulted in 15 patents for the more general area of metal deposition.

The search for sensor or control systems for metal deposition resulted in two patents (US5233150 and US122564). Both patents also contain information belonging to the general search so it is already presented above

The patents can be sorted into different groups depending on what in metal deposition the invention is aiming to improve or accomplish. Table 1 lists the number of patents sorted in the respective groups. Some of the patents contain information possible to classify into many of the groups and have therefore been sorted into all the suitable groups, see Appendix B for details.

Area	Quantity
Generate robot path	4
Build process	11
Machine type	7
Build planning	4
Sensor and control	2

**Table 1** – Shows different areas to sort the patents into. One patent can be sorted under more than one area if the patent contains inventions covering more than one area. In Appendix B an overview of which patent that has been sorted into which area can be seen.

In the generate robot path methods of how to create the path for the robot to create the wanted feature are presented.

In the build process the patents describes different ways to change or improve the outcome of the metal deposition process.

In machine types different machines used for metal deposition are presented. All of the Rolls Royce (six of the seven) describes the same robot based metal deposition system while the remaining patent, EP0529816 describes the use of a CNC-machine for metal deposition.

The build planning area covers guidelines on how to develop the path to generate the best result.

The sensor and control section contains the two patents that describe control systems.

## **4 Analysis**

The patents presented in this report and the information presented in the patent summaries are at this point of time considered to be relevant for the project. In a later stage of the project other patents can become relevant for the project. Also a different part of the patents presented than described in the patent summaries can become relevant for the project in a later stage.

Of course the half page summaries presented are not a substitute for the complete patent documents usually containing between 10 and 20 pages. Instead the summaries could be used as a quick reference when trying to find the right patent document or as a short introduction of patents for metal deposition.

If further information is needed the full-text patents should be available at:

<http://www.uspto.gov/patft/index.html> or  
<http://ep.espacenet.com/>.

Very few patents for sensor and control systems were found. One of the reasons could be that the sensor and control systems used for metal deposition are common techniques. If this is the case the patents will be found searching for “sensor and control system” instead of metal deposition sensor and control system. No search on this field has been conducted due to the fact that too much information (EPO web site generates 24501 hits when searched for “sensor control system” in title or abstract).

Another reason could be that the area for automated metal deposition has not yet been properly researched.

## **5 Conclusions**

From the patent search the conclusion that metal deposition research is conducted at many different sites around the world and the research is focused on a lot of different areas of metal deposition. The area where very few inventions and developments can be found in the patents is the sensor and control for metal deposition. This is the main area of the research conducted of the MIA-group at HTU. The lack of patents on the focused area opens great prospects for the research conducted in the MIA-group.

Three of the patents mentioned have similarities to work done within two thesis works conducted at HTU.

Patents US6274839 and US5233150 have similarities with “MD Banplanering och simulering” by Mr Jonas Berg and Mr Jarmo Luukkonen.

Patent EP1245322 has similarities with “Development of Sensor System for Automated Metal Deposition” by Mr Simon Cronholm, Mr Jan-Erik Henriksson and Ms Jessica Jansson.

## **6 Recommendations for further work**

To keep the patents report up to date a regular search of the patent archives should be conducted. This would also allow the patent report to change its focus as further development and change of the metal deposition research proceeds.

A second patent search would also be useful when the outline of the sensor and control system is starting to be finished. The reason for not conducting the research right away and incorporate it into this report is that a general search for “sensor control” generates a lot of patents (almost 56,000 hits using the EPO web site) and a analysis of the patents will not be possible due to too much information.

## **Unpublished References**

J-E. Henriksson, J. Jansson, S. Cronholm. *Development of Sensor System for Automated metal deposition*. Högskolan Trollhättan Uddevalla. 2004:RT03.

J. Luukkonen, J. Berg. *MD Banplanering och simulering*. Högskolan Trollhättan/Uddevalla. 2004.

## A First Appendix

### European classification of patents

The European classification of patents was created by the European Patent Office (EPO) to be used as a common classification of patents for the EPO member countries. The EPO website is located at:

<http://www.european-patent-office.org/>

and the patents search site, where all the information presented can be found, is located at:

<http://ep.espacenet.com/>

and then click on the “Classification Search” button.

When a new patent is approved it is sorted into one or more groups that contain similar patents. If no suitable group can be found a new one is created by EPO.

The most common group for metal deposition patents is B23K9/04, but what do the different letters and numbers mean?

The first letter, B means that the patent is sorted under “Performing operations; Transporting”.

There are eight different letters that are used, from A to H with the area according to Table A-1.

<i>Letter</i>	<i>Area</i>
A	Human Necessities
B	Performing operations; Transporting
C	Chemistry; Metallurgy
D	Textiles; Paper
E	Fixed constructions
F	Mechanical engineering; Lighting; Heating; Weapons; Blasting engines or pumps
G	Physics
H	Electricity

**Table A-1** - Science areas represented by the first letter for European classification of patents.

The second part of the classification is 23 and represents the area “Machine tools; Metal-working not otherwise provided for”. There are numbers between 01 and 82 but all the numbers are not used, e.g. a gap between 68 and 81.

Some examples of numbers and area can be seen in Table A-2.

<i>Number</i>	<i>Area</i>
B22	Casting; Powder metallurgy
B23	Machine tools; Metal-working not otherwise provided for
B24	Grinding; Polishing
B30	Presses
B64	Aircraft; Aviation; Cosmonautics
B82	Nano-technology

**Table A-2** – Example of areas found under European classification of patents letter B.

The third part of the classification is a letter, in our example K. The K represents the group “Soldering or unsoldering; Welding; Cladding or plating by soldering or welding; Cutting by applying heat locally, e.g. flame cutting; Working by laser beam”. There are nine different letters, each representing one group with examples in Table A-3.

<i>Number</i>	<i>Area</i>
B23B	Turning; Boring
B23C	Milling
B23K	Soldering or unsoldering; Welding; Cladding or plating by soldering or welding; Cutting by applying heat locally, e.g. flame cutting; Working by laser beam
B23P	Other working of metal; Combined operations; Universal machine tools

**Table A-3** – Example of areas under B23 for European classification of patents.

The next part of the classification is a number, in our example 9. The 9 represents the group “Arc welding or cutting”. Other groups with their numbers can be seen in Table A-4.

<i>Number</i>	<i>Area</i>
B23K5	Gas flame welding
B23K9	Arc welding or cutting
B23K10	Welding or cutting by means of plasma

**Table A-4** – Example of numbers and areas under B23K of European classification of patents.

The last part of the classification is first a slash (/) and then an other number. In our example /04 that represents the area “Welding for other purposes than joining, e.g. built-up welding”. Examples of other areas are presented in Table A-5.

<i>Number</i>	<i>Area</i>
B23K9/04	Welding for other purposes than joining, e.g. built-up welding
B23K9/095	Monitoring or automatic control of welding parameters
B23K9/12	Automatic feeding or moving of electrodes or work for spot or seam welding or cutting

**Table A-5** – Example of areas under B23K9 for European classification of patents.

## **B Second Appendix**

### **Area of improvement presented by the patents**

#### **Generate robot path**

US6274839  
EP1354658  
US6122564  
US2002110649

#### **Build process**

EP1245323  
EP1302269  
EP1245322  
EP1354658  
EP0529816  
US6143378  
US5578227  
US4323956  
EP1281467  
GB2373749  
US2002110649

#### **Machine type**

US6274839  
EP1245323  
EP1302269  
EP1245322  
US2002139779  
EP1354658  
EP0529816

#### **Build planning**

EP1245322  
US2002139779  
EP1354658  
US5233150  
US6122564

#### **Sensor and Control**

US5233150  
US6122564

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