patent trademark design
Norwegian Industrial
Property Office

Joining of materials

A patent landscape analysis

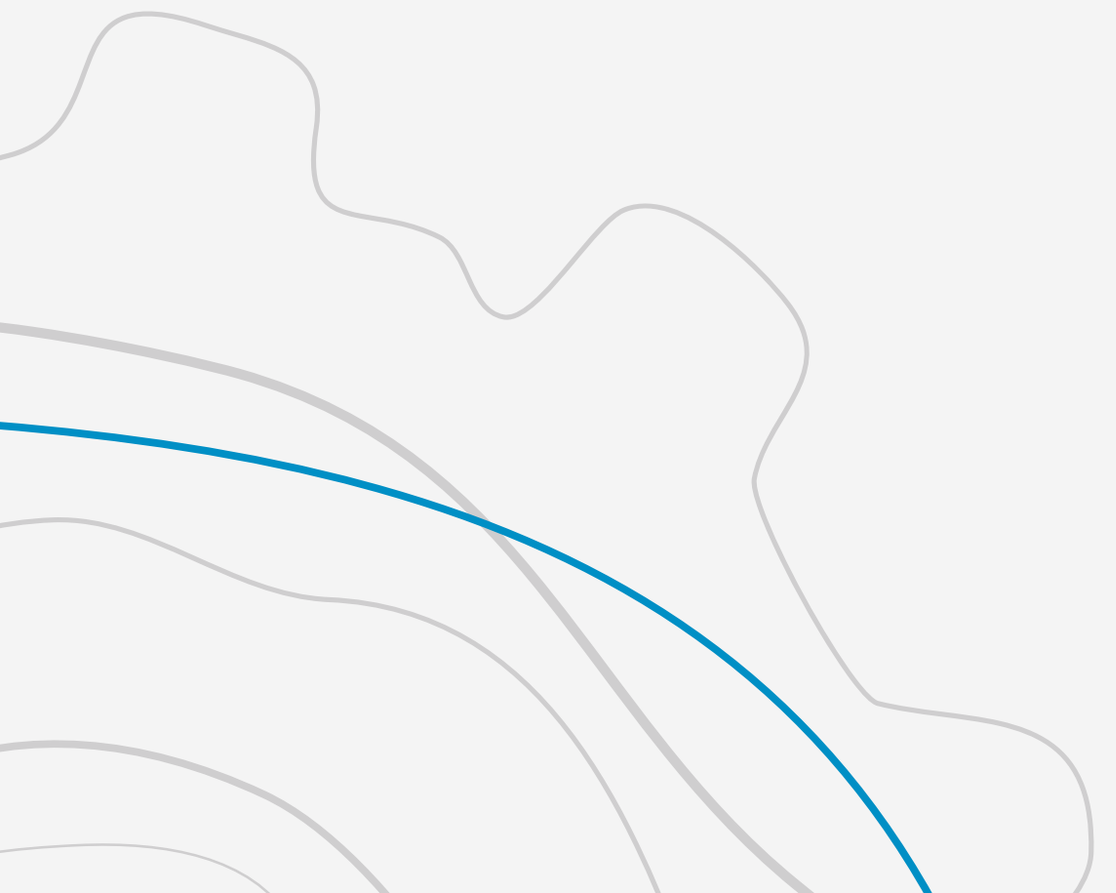
A national centre for intellectual property rights

The primary role of the Norwegian Industrial Property Office (NIPO) is to promote innovation and value creation, both as national intellectual property rights authority and as a guide and knowledge provider.

NIPO contributes to competitiveness and helps to strengthen Norwegian trade and industry in various ways. We provide knowledge and expertise concerning intellectual property rights and values, enabling businesses to secure their investments, their competitive position and create economic growth in Norwegian society.

What are Intellectual Property Rights?

Intellectual Property Rights (IPR), are legal monopoly rights that protects inventions, names, logos, designs and other innovations. Strategic use of these rights can make IPR to the most valuable assets of your business.



Summary

This report is based on a collaboration between the Norwegian Industrial Property Office and the Research Council of Norway as a measure to bring knowledge of IPR (Industrial Property Rights) into public funded research projects. The report aims to uncover opportunities and challenges in IPR by mapping the patent landscape in the technical area.

Understanding the global patenting environment is an important factor for making good strategic decisions within IPR. However, the aim of this report is not to give any advice on strategic decisions, but rather to present the available patent data within the technological areas to form a platform of knowledge for making the right decisions. The nature of IPR is complex, and there are several different schools of thoughts related to IP strategy. If you are not aware of your competitors IPR, it can cause you a lot of trouble and become expensive. Likewise, in the ever-increasing complexity of the technical field, it is also important to protect your own unique knowledge and ideas, both to secure the exclusive rights to your own invention, and to achieve more benefits in negotiations with investors, partners and potential licensees.

The aim of this report is therefore to provide an overview of the patent data within the technology of joining. The report also comprises an analysis of the patent activity within this technological field, and a more detailed analysis of the five different metal joining methods.

Two patent data sets were gathered and used for further analysis, one larger set for an overview of the technical area, and one dataset consisting of five subareas chosen in collaboration with SFI Manufacturing as key research areas within welding technology.

Analysing the global patent environment for the joining technology as such makes it clear that USA holds the leading role. For both metal and polymer joining, and for additive manufacturing, USA is the largest provider of patent applications, followed by Japan, Germany and China.

For the welding methods in the five data subsets, the patenting environment is quite similar as for the larger data set, with USA, Japan and Germany among the top four priority countries for all the methods. France, China, Russia and Great Britain are also important countries within these methods. Based on the degree of patent extensions, all the top priority countries are internationally focused, with the exception of Russia, China and Korea, which to a much lesser degree extend their patent applications.

When looking at the historical patenting development for the joining technology, the curves are increasing for all three joining technologies, indicating that the technology is still under development. Showing metal joining separately as mechanical and thermal joining, the numbers clearly show that the increase is mainly within thermal joining. Consequently, the same increase is observed for the five welding methods in this report.

Even though the metal industry, both production and processing, holds a strong tradition in Norway, the number of patents is rather low. The industry in Norway has built up a collaboration network, where information to a certain degree flows between the companies. However, production and process details often seem to be kept as a business secret rather than protected and published through the patent system. Anyway, this report shows that patent applications from Norway, although they are rather few, mostly are extended to the top countries within the technology, showing the same trend as for the global patenting environment.

The Research Council of Norway

sfi Centre for Research-based Innovation
The Research Council of Norway

manufacturing

patent trademark design
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Background

IPR within the joining technology

The method

Joining of materials is a large technology area that covers many different branches. There are several joining technologies and material types, giving a large number of combinations of techniques. The process of joining can be divided into three groups: mechanical, chemical and thermal. The material types comprise metals, polymers, composites, ceramics and glass. Welding is one of the most used joining techniques, see Figure 1. Welding history is traced back to Egypt 4000 years B.C. with copper as the first metal used, followed by bronze, silver, gold and iron.

Even though different methods of joining have been used since time immemorial, the technology is still in development, with new materials and new methods of joining. The development, measured by the number of patent documents, has increased the last decade, indicating that this ancient method is still full of surprises.

New technology comes to use within the field of joining, giving new and more efficient methods that are more adapted to the materials used.

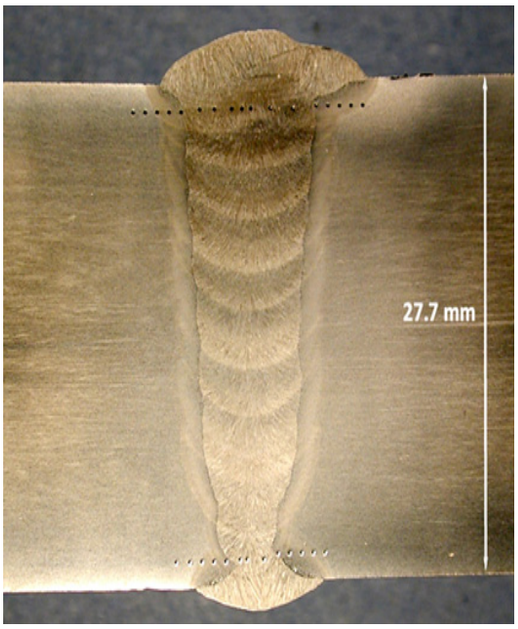


Figure 1: A typical weld

Norway[1]

The Norwegian manufacturing industry employs about 240 000 people or 9% of the total employment. There has been a rise in employment and value creation since 2005, mainly due to high investment activity in the petroleum business and more export due to favorable currency. The total revenue was 753 billion NOK in 2014.

The main manufacturing industry sectors are:

- Food and beverages
- Production of machinery (especially to ships and offshore installations)
- Process industry
- Aluminum finished products

The process industry (metallurgical industry, pulp, paper, fertilizers, chemicals and pharmaceutical industry) stands for half of the export from Norway (not including oil and gas). The use of low cost hydropower as electric energy source has a more than 100 years history in Norway. World-class companies, research institutions and universities are developing the industry for the future, using biocarbon and hydrogen instead of coke and coal. The industry has been in forefront in developing solar grade silicon and process equipment for the metallurgical and solar industry. Advanced high value products have been developed from the side streams of the main production, utilizing all the raw materials. Most of the process industry is today owned by global companies, and many of these have located their research and development centers in Norway.

1 text from http://www.innovasjonnorge.no/en/start-page/invest-in-norway/industries/ and http://www.innovasjonnorge.no/en/start-page/invest-in-norway/industries/manufacturing-and-process-industries/

Regarding aluminum finished products, Norway's position in primary aluminum production and manufacturing capacity of aluminum finished products have been developed to be in the international forefront. Aluminum parts production for automotive, extruded products for construction, and parts in consumer products are increasing their worldwide market share.

SINTEF and SFI Manufacturing[2]

For more than 60 years, SINTEF has developed solutions and innovation for society and customers all over the world. This is how they have become a world-leading research institute.

SINTEF is a broad, multidisciplinary research organization with international top-level expertise in the fields of technology, the natural sciences, medicine and the social sciences. They conduct contract R&D as a partner for the private and public sectors, and they are one of the largest contract research institutions in Europe, see Figure 2.

SFI Manufacturing is a cross-disciplinary centre for research based innovation for competitive high value manufacturing in Norway. The research centre was officially established on July 1st 2015.

2 text from SINTEF and SFI Manufacturing webpages. Additional information can be found in the Annual Report of 2016 http://www.sfimanufacturing.no/annual-reports.html

SFI Manufacturing's vision is to show that sustainable manufacturing in a high-cost country like Norway is possible, given the right products, technologies and people. Cross-disciplinary research will provide a knowledge based toolbox for future industrial innovations.

Research areas:

- Multi-Material Products and Processes
- Robust and Flexible Automation
- Innovative and Sustainable Organizations

Budget:

In November 2014, The Research Council of Norway (RCN) announced 17 new SFI centres, of which SFI Manufacturing is one. In the eight years to come, The Research Council will be allocating roughly NOK 1.6 billion to the new centres. Each centre receives roughly 10 MNOK per year from RCN. The host institution and partners must contribute with at least the same amount.

The pilot project

SFI Manufacturing was one of the early stakeholders interested in participating in the pilot project from the Norwegian Industrial Property Office offering patent landscape analysis to Norwegian research centres participating in the SFI program. SFI Manufacturing requested a landscape analysis within the subject: joining of metals, joining of polymers and additive manufacturing.

Figure 2: SINTEF Facts

We started the project in April 2016 after communication between representatives from SFI Manufacturing and the Norwegian Industrial Property Office to be sure the topic was clearly understood. After preliminary searches on the topics joining of metals, joining of polymers, and additive manufacturing, the search results were massive. The number of relevant documents within this broad search field was too large to handle in further analysis.

In understanding with SFI Manufacturing, the project was scaled down to 5 different welding techniques within the subject joining of metals. This would give search results that could be analysed in a better way, giving a better picture of the patent landscape.

Interpretation of patent data

When looking at a patenting environment, it is important to view it from the right perspective. As an example, a large number of patent applications from a competing nation in a competing field of technology may not always be of great concern. Several aspects have to be taken into account.

Patent applications may have different vital and legal statuses. A patent application's ability to be enforced depends on its legal status, which may range from declined to granted. A declined patent application is most useful in the sense that is adds to the prior art, but may not be eligible for legal enforcement. A granted patent application can however be legally enforced and is therefore a greater threat to a competitor.

The patents may also have a variety of vital statuses. The vital status may be dead, pending or alive. The vital status is not taken into account in this report, but as a rule of thumb, most patents have a maximum lifespan of 20 years.

Some applications may also be filed as utility models (see glossary), especially this applies to applications with Chinese priority. This is very similar to patent applications, but they have a lifespan from 6 to 10 years with less stringent patentability requirements.

The patent data search for this report is aimed at gathering as many patent publications as possible within the technologies, as well as filtering out irrelevant patent publications.

Before deciding on IPR strategies, it is important to have insight in the global patenting environment, such as this report provides. The aim of this report is therefore not to advice on strategic decisions, but rather to present the available patent data to provide a good basis for the decision.

2

Methodology

Dataset overview

In this report, the focus has been both on the large data set of joining as such and on the sub sets of data from the five different techniques of metal joining. This provides two different analysis; the larger data set gives an overview and a glimpse of the technology landscape, while the sub data sets give a more detailed analysis of the patent activity within the different technological areas.

The basis for the technical scope of this report is the large data set and the sub sets listed in Table 1.

Search strategy

The report has been carried out based on searches in the European Patent Organisation DOCumentation database (EPODOC) and Derwent Thompsons World Patent Index database (WPI). The documents in the databases consist of published applications, granted patents as well as classified non-patent literature (XP documents).

1. COLD METAL TRANSFER (CMT)
2. COLD PRESSURE WELDING (CPW)
3. FRICTION STIR WELDING/ LASER ASSISTED FRICTION STIR WELDING (FW)
4. RESISTANT SPOT WELDING (RSW)
5. DISSIMILAR MATERIALS, STEEL/ ALUMINIUM WELDING

Table 1: The different areas of technology

The patent data was gathered from September to November 2016. The data subsets on the different metal joining technologies were cut-off in 2014. This was due to an uncertainty of the total coverage of data from 2015. An incomplete set of data from 2015 could provide a wrong image of the development within the technology, mainly because the total number of data in some of these subsets was relatively small, due to publication rules of patent documents.

A combination of classification and full text search has been carried out to get relevant search results. In the full text search, query search and classification search has been combined. In addition, backward and forward citation searches has been conducted. Each search result has been filtered and later grouped into the different technical areas.

Patent classification overview

The patent data set in this report comprises a large number of publications with different patent classifications. Table 2 illustrates the main relevant patent classifications for each area. The overview contains classes from both the International Patent Classification (IPC) system and the Cooperative Patent Classification (CPC) system. The subsets of the different metal joining technologies are also part of the larger data set of metal joining.

All patent documents are classified according to a hierarchical classification system. The classification scheme organizes all patent documents based on the technical field of the invention. This provides a retrieval system by subject matter, regardless of the industrial sector, actual keywords used in the application. Thus, it goes to the core of what is protected by the patent.

Search results

The difference in sizes between the data subsets may reveal the difference in patenting frequency in these technical areas. Small datasets may indicate less developed areas. However, the sheer number of relevant patents alone does not represent the level of invention in each technical area. This can merely indicate that the technical area is relatively new. The annual development of patenting within each area, which is described in the trend analysis, may provide a more accurate indication of the patenting frequency. The data set analysis is described in further details in the next chapter.

	Area 1	Area 2	Area 3	
	Metal joining	Polymer joining	Additive manufacturing	
B01D Working or processing of sheet metal or metal tubes, rods or profiles	39/00/low			Patent classification
B21F Working or processing of metal wire	15/00/low			
B21J Forging; Hammering; Pressing metal; Riveting	15/00/low*			
B21K Making forged or pressed metal products	25/00/low			
B21L Making metal chains	3/00/low			
B22D Casting of metals	19/04/low			
B23K Soldering or unsoldering; welding; cladding or plating	1/00/low*, 5/00/low*, 9/00/low*, 10/02/low, 11/00/low*, 13/00/low*, 15/00/low*, 17/00, 20/00/low*, 23/00, 25/00, 26/00/low*, 28/00/low*, 31/00/low*, 33/00/low, 35/00/low*			
B23P Other working of metal; Combined operations	11/00/low, 19/00/low*			
B29C Shaping or joining of plastics		65/00/low; 66/00/low	67/0051/low**	
B33Y Additive manufacturing			10/00, 30/00, 40/00, 50/00/low, 70/00, 80/00, 99/00	
C09J Adhesives		5/00/low		

* only relevant parts of the subclass is searched
** reclassified in 2017 to new class B29C 64/00/low

Table 2: Patent classification overview for the patent data set

3

Statistical analysis

Overview of the technical area

This chapter is focused on the whole data set in order to get a large scale overview of the patenting environment within the field of joining of materials.

Results of the search

- Total number of patent documents*: 673 300
- joining of metal: 433 400
- joining of polymer: 218 300
- additive manufacturing: 21 600

* Both applications and granted patents

Figure 3 shows the geographical extent of the patent documents on the three technical areas for the years 1996-2016 (notice the difference in the scale of the y-axis). The figures show the top 15 priority countries together with EP and WO (applications filed to EPO and WIPO).

Figure 4 shows the total number of patent documents filed over the years within the three technical areas, and accordingly the patent activity over the years.

In Figure 5, the data for metal joining are split up into mechanical and thermal joining, and we are able to see the number of patent documents on each technique over the years.

Statistical Analysis

Figure 3 shows the number of patent applications filed in each country, and hence the patent activity within the technical field. This gives an indication of where the technological development is taking place, and where the market for this technology is found. This can be helpful information for a patent applicant when considering where to file the patent applications. The information can also be helpful for companies wanting to access the market, indicating in which countries the technology is developed and where to find potential partners, both for development and business.

For metal joining, the figure shows that the major part of the applications are filed in USA, Japan, Germany and China, together with applications filed through WIPO's PCT-system (WO). The fact that so many patent applications are filed directly to WIPO can indicate that patent assignees from outside USA, Japan, China and Germany (where the patenting activity is high), prefer to use the PCT-system for their applications rather than filing an application in their resident country.

The figure shows the same trend for top priority countries for polymer joining as for metal joining, with most of the applications filed in USA, Japan, Germany and China. However, for polymer joining there are more applications filed to EPO, and the number of applications filed to WIPO is relatively low. This can indicate that the major part of the polymer joining technology development and patent activity is taking place in Europe.

For additive manufacturing, the total number of applications filed is substantially smaller compared to metal and polymer joining (Figure 3). This is because this technique is relatively new. However, comparing the graph with the one for metal joining shows that the trend is similar; with USA, Germany, China and Japan being the top countries with the most applications filed, together with applications to WIPO's PCT-system.

In the trend analysis, we look at the patenting development over the years (Figure 4). First, the large number of documents over time implies that joining is a historical important technical area. Second, the large increase in patent documents in the later years shows that this technology is still in growth, and that the technological development is growing even faster over the last decade. This is an area with growing innovation and development.

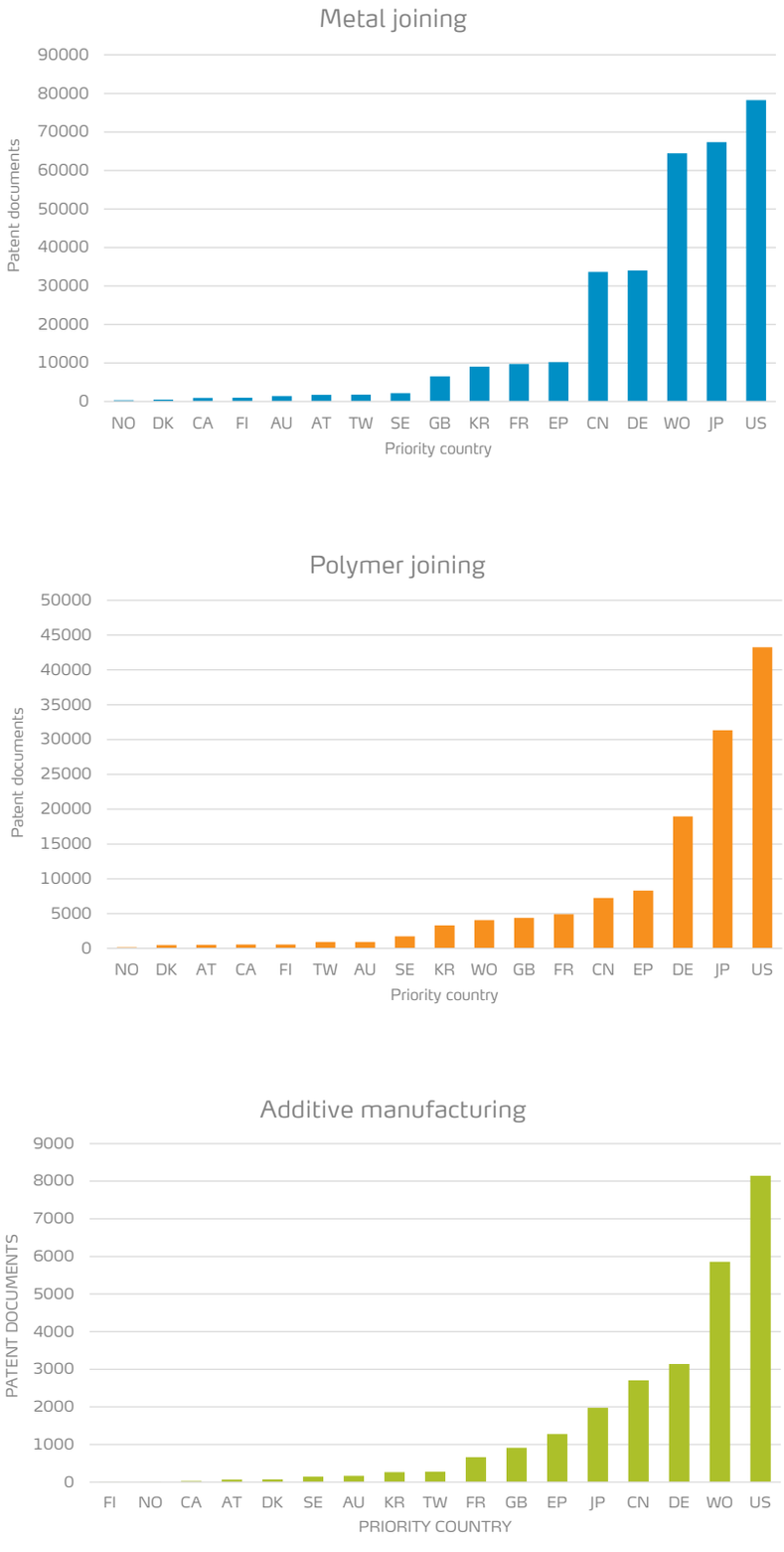
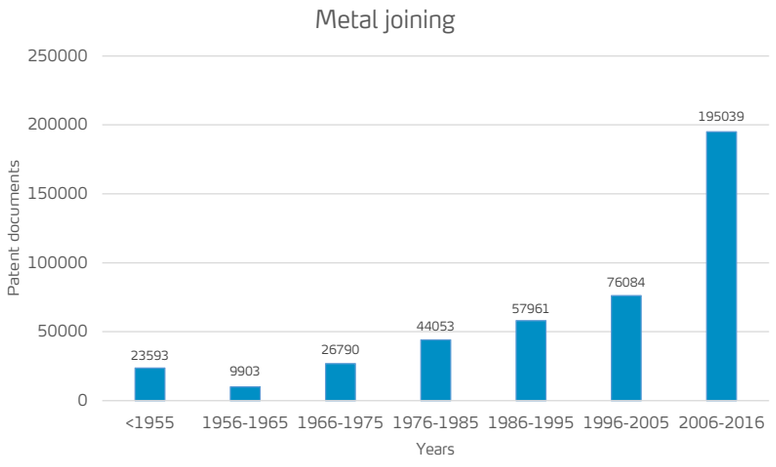
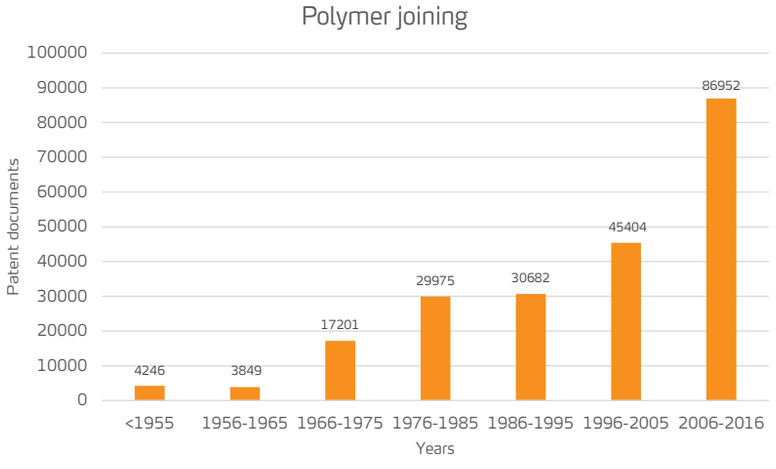


Figure 3: The patenting activity in 15 countries + EP and WO applications





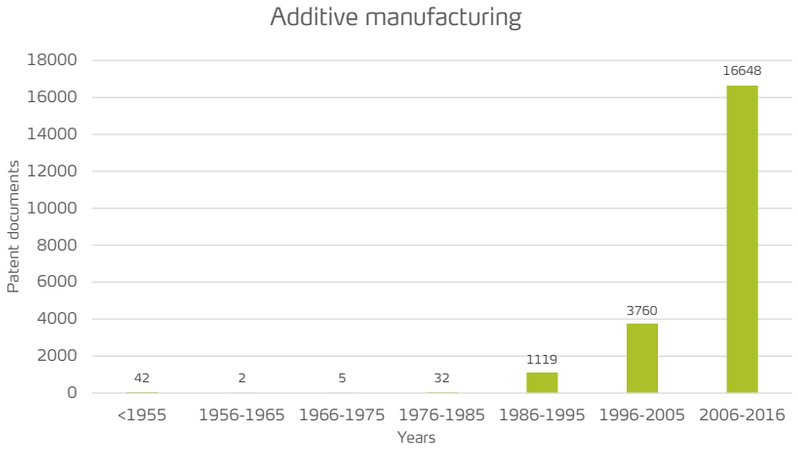


Figure 4: Figure 4 shows the number of patent documents (both applications and granted patents) over the years

The figure shows that the development of metal joining is increasing, with continuously increasing number of patent documents. Figure 5 shows that the major part of the growth is within thermal joining, as has been the situation since time immemorial.

For joining of polymers, Figure 4 shows that the development is similar to the one for metal joining, indicating the same continuously increasing development within this technology.

However, the total number of patent documents within additive manufacturing is low compared to the number for metal and polymer joining (Figure 4). In addition, most of the patent documents are filed the last decade. These two factors reveal that this is a relative new technological field in growth.

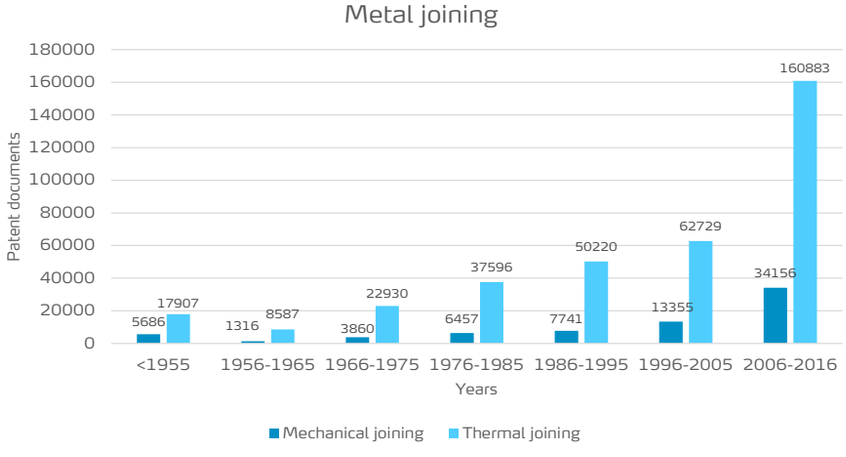


Figure 5: The number of patent documents for metal joining, where mechanical and thermal joining are split up.

Metal joining - 5 welding techniques

The large number of patent documents within the technological field of metal joining makes it difficult to perform good analysis on the data. Therefore, in agreement with SFI Manufacturing, we chose to focus on five welding techniques.

The analysis was therefore performed on the following:

- Cold metal transfer welding (CMT)
- Cold pressure welding (CPW)
- Friction welding (including friction stir welding and laser assisted friction stir welding - FSW)
- Resistance spot welding (RSW)
- Joining dissimilar materials – steel/aluminium welding

Cold metal transfer welding

Cold metal transfer (CMT) welding is a modified metal inert gas (MIG) welding process based on short-circuiting transfer process. Cold metal transfer provides controlled method of material deposition and low thermal input. When the electrode tip makes contact with the molten pool, the wire retracts promoting droplet transfer. During metal transfer, the current drops to near-zero and thereby any spatter generation is avoided. As soon as the metal transfer is completed, the arc is re-ignited and the wire is fed forward once more with set welding current reflowing. This method is also widely employed for welding of dissimilar metals such as aluminium and steel [1].

Cold pressure welding

Cold pressure welding (CPW) is performed at ambient temperatures and relies upon the use of high compressive pressure to join the metals together. The pressure causes the oxide film on the surface to break up to reveal clean surfaces that bond due to the intimate contact. The method is applicable to soft ductile metals [2].

Friction stir welding

Friction stir welding (FSW) uses a non-consumable rotating tool to join to sheets or plates together. The friction made by the rotating tool creates heat and movement to the material to produce the joint [3]. Laser assisted friction stir welding (LAFSW) is a combination of FSW and laser welding. LAFSW uses laser power to preheat the workpiece before the rotating tool creates the friction to produce the joint. Then less mechanical energy must be converted to heat, and this reduces the tool forces and may enable higher weld speeds [4].

Resistance spot welding

Resistance spot welding (RSW) is the most common of the various resistance welding processes. In this process, the weld is produced by the heat obtained at spots on the interface between the workpieces. This heat is due to resistance to the flow of electric current through the workpiece [5].

Joining dissimilar materials - steel and aluminium welding

Joining of aluminium to steel offers a unique set of metallurgical challenges that must be addressed to achieve a successful welding method. These challenges include differences in melting points, as well as coefficients of both thermal expansion and conductivity.
Combining aluminium with steel offers considerable flexibility in design and functionality of engineered structures, especially in the automotive industry. Considerable effort has been placed in defining candidate welding and joining technologies over the last few years [6].

1 S. Selvi et al. "Cold metal transfer (CMT) technology – An overview», Defence Technology (2017)
2 http://www.coldpressurewelding.com/home/what-is-cold-pressure-welding

3 R.S. Mishra et al. «Friction stir welding and processing", Materials Science and Engineering: R: Reports, Vol. 50, 1-2 (2005) p. 1-78.
4 S.L. Campanelli et al. «Analysis and Comparison of Friction Stir Welding and Laser Assisted Friction Stir Welding of Aluminium Alloy", Materials (Basel) 6 (12), (2013) p. 5923-5941.
5 L. F. Jeffus "Welding: Principles and Applications", Cengage Learning (2014) p. 694-695.
6 J.E. Gould et al. "Critical Metallurgical and Processing Elements for Welding Aluminium to Steel", EWI (2016).

Geographical coverage of patents

In this chapter, we will enlighten the geographical coverage of patent applications (first filings) and their originating countries for the 5 welding methods in question. The data on priority and extension countries for each method can give valuable information on the technology.

Worldwide patent coverage

Figure 6 shows the percentage distribution of the priority patent documents for each of the welding methods. This can indicate in which countries the technology is developed and where the main market for the technology is. The figure shows that USA, Japan, Germany and China are among the top 5 priority countries for all the welding methods. This indicates that these are important markets for this technology. France, Great Britain, Russia and Korea are also important countries with high filing rates for several methods. For the cold metal transfer welding method, Austria is also among the top 5 priority countries, indicating that this technology is of importance in this country.

Tables showing the total number of priority applications and countries is enclosed in the Appendix C.

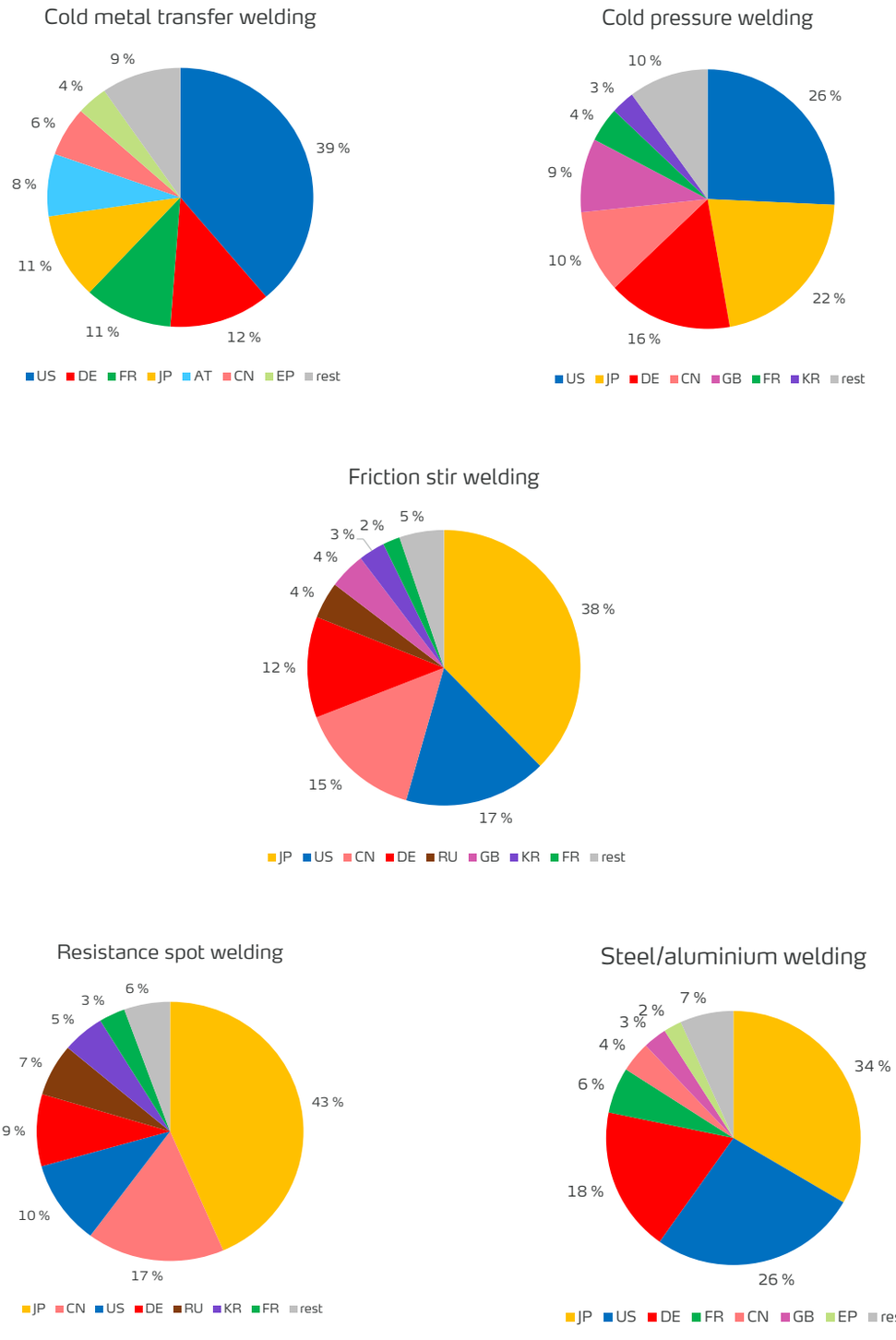


Figure 6: The distribution of the priority patent applications for the different welding methods

International patent extensions

Tables 3-7 provide an overview of where the patent applications are being extended to (vertical axis) and where they are extended from (horizontal axis) for each of the methods.

Extension country/region	Priority country/region														
	US	DE	JP	FR	AT	CN	EP	GB	KR	SE	CH	TW	RU	IT	LU
US	0	9	8	11	22	1	4	5	3	1	1	2	1	1	1
DE	41	0	8	3	11	0	2	6	1	0	1	0	2	1	1
JP	41	5	0	7	20	1	1	3	0	0	1	0	1	2	0
FR	15	2	0	0	0	0	0	0	0	0	1	0	0	1	1
AT	11	0	0	1	0	0	2	1	0	0	0	0	0	1	1
CN	27	7	2	5	19	0	4	0	1	1	0	1	0	1	0
EP	51	17	6	15	24	1	0	4	1	1	0	0	0	2	0
GB	15	1	0	1	0	0	2	0	0	0	1	0	0	1	1
KR	19	2	3	2	1	1	1	1	0	0	0	0	0	1	0
AU	32	0	0	4	0	0	0	4	0	0	2	0	0	2	2
BE	6	0	0	1	0	0	0	1	0	0	0	0	0	1	1
SE	4	0	0	0	0	0	0	1	0	0	0	0	0	0	1
CH	2	1	0	1	0	0	0	1	0	0	0	0	0	0	1
TW	14	0	2	1	0	0	0	0	0	0	0	0	0	0	0
RU	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
IT	8	2	0	0	0	0	0	0	0	0	1	0	0	0	1
MX	6	0	0	1	0	0	1	0	0	0	0	0	0	0	0
LU	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CA	30	0	3	6	0	0	2	2	0	0	1	0	0	2	1

Table 3: The geographical coverage of patent applications from their priority countries (horisontal axis) to their respective extension countries (vertical axis) for the method cold metal transfer welding (CMT).

Extension country/region	Priority country/region																
	US	JP	DE	CN	GB	FR	KR	EP	BE	CH	RU	SE	IT	TW	AT	NL	CA
US	0	200	109	23	109	58	24	21	1	13	6	11	6	7	3	3	2
JP	133	0	55	17	32	36	16	9	1	6	2	6	6	0	3	3	1
DE	145	97	0	1	63	39	10	13	2	11	7	12	15	0	4	7	1
CN	65	70	30	0	8	23	16	15	1	2	1	4	1	0	2	0	0
GB	49	13	42	0	0	10	2	0	0	9	2	5	1	0	1	4	1
FR	35	13	30	0	13	0	2	0	0	10	3	5	2	0	1	2	1
KR	40	52	11	13	3	8	0	7	0	0	0	0	0	0	2	0	0
EP	151	85	142	16	71	59	1	0	1	3	2	6	11	0	4	1	0
BE	10	0	13	0	5	6	0	0	0	4	0	0	1	0	0	3	0
CH	16	2	20	0	6	4	0	0	0	0	0	0	3	0	0	1	0
RU	5	2	5	1	3	16	0	1	1	0	0	0	2	0	1	0	0
SE	16	2	7	0	3	3	0	0	0	5	4	0	1	0	0	2	0
IT	14	3	14	0	6	1	1	0	0	3	0	2	0	0	0	2	1
TW	23	28	3	1	1	1	3	6	0	1	0	0	1	0	0	0	0
AT	17	2	40	0	24	8	0	6	1	6	0	1	5	0	0	1	0
NL	17	0	9	0	8	3	0	0	0	3	0	0	2	0	1	0	1
RO	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
CA	82	26	20	10	19	26	0	2	1	3	0	2	3	0	2	3	0

Table 4: The geographical coverage of patent applications from their priority countries (horisontal axis) to their respective extension countries (vertical axis) for the method cold pressure welding (CPW)

Extension country/region	Priority country/region															
	JP	US	CN	DE	GB	KR	FR	EP	RU	TW	SE	AT	CH	NL	IT	NO
JP	0	257	22	181	93	12	65	17	2	2	20	14	7	7	4	6
US	488	0	39	380	186	25	113	43	3	11	31	15	8	25	9	7
CN	311	202	0	129	34	14	42	23	1	4	7	4	4	0	4	2
DE	246	219	1	0	137	6	65	20	5	1	25	13	13	51	4	7
GB	23	90	0	49	0	3	19	0	2	1	7	2	5	11	1	2
KR	185	66	14	50	17	0	6	10	0	1	5	8	0	2	2	2
FR	15	36	0	56	26	0	0	0	0	0	5	3	9	9	1	1
EP	265	321	18	540	139	4	92	0	1	0	21	17	7	7	6	8
RU	4	19	0	23	14	0	24	3	0	0	3	4	1	1	1	2
TW	89	20	4	4	10	0	1	0	0	0	0	1	2	0	0	0
SE	0	9	0	21	11	0	3	1	0	0	0	2	4	12	0	1
AT	33	38	0	86	36	0	20	9	2	0	10	0	8	11	1	1
CH	0	6	0	16	5	0	9	0	0	0	3	1	0	5	1	0
AU	76	116	0	28	65	1	17	7	1	0	27	8	5	0	1	10
NL	0	8	0	20	9	0	9	1	0	0	3	1	3	0	1	1
RO	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
IT	5	11	0	31	9	0	8	0	0	0	4	0	3	3	0	2
NO	6	8	0	11	24	0	5	1	0	0	10	4	0	4	0	0

Table 5: the geographical coverage of patent applications from their priority countries (horisontal axis) to their respective extension countries (vertical axis) for the method friction stir welding (FW)

Extension country/region	Priority country/region																	
	JP	CN	US	DE	KR	FR	GB	BE	IT	AT	RU	EP	TW	CH	SE	PL	NL	AU
JP	0	4	85	71	16	30	13	0	18	24	1	4	1	7	8	1	7	1
CN	168	0	62	61	30	10	2	0	7	13	1	8	4	1	1	0	2	1
US	378	11	0	163	37	41	22	2	22	27	4	12	5	9	15	0	23	1
DE	208	5	133	0	19	77	33	4	30	36	3	8	2	13	12	2	45	0
KR	108	2	9	21	0	5	2	0	3	2	0	3	0	1	2	0	1	0
FR	25	0	27	40	0	0	9	0	9	6	0	0	0	6	1	1	8	0
GB	74	4	36	39	0	14	0	0	7	6	0	1	0	5	0	1	10	0
BE	2	0	9	9	0	4	5	0	5	6	0	0	0	2	0	1	7	0
IT	3	0	19	20	0	4	1	0	0	3	0	0	0	0	0	1	2	0
AT	11	0	8	43	0	19	5	1	10	0	1	6	0	3	4	0	7	0
RU	2	0	2	14	1	6	0	1	11	5	0	2	0	0	1	0	1	0
EP	167	1	73	253	6	55	19	2	28	35	3	0	0	5	9	0	4	1
TW	19	1	3	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0
CH	0	0	5	16	0	2	1	0	1	7	0	0	0	0	0	0	5	0
SE	3	0	16	16	0	6	1	0	6	3	1	0	0	1	0	1	11	0
PL	0	0	1	3	0	1	0	1	3	1	0	1	0	0	0	0	0	0
NL	1	0	3	17	0	4	5	0	1	4	0	0	0	4	0	0	0	0
AU	27	0	53	26	0	2	16	0	1	3	0	2	0	2	3	0	2	0

Table 6: the geographical coverage of patent applications from their priority countries (horisontal axis) to their respective extension countries (vertical axis) for the method resistance spot welding (RSW)

Extension country/region	Priority country/region																	
	JP	US	DE	FR	CN	GB	EP	BE	KR	CH	IT	AT	AU	NL	CA	SE	ES	NO
JP	0	69	31	28	2	8	7	0	4	1	2	1	1	0	1	2	0	2
US	146	0	82	43	8	15	14	1	6	3	2	3	1	1	1	2	0	2
DE	75	99	0	26	2	9	10	0	1	1	4	3	0	0	1	1	0	2
FR	10	24	14	0	0	6	0	0	0	1	2	0	0	0	0	1	0	0
CN	62	51	38	17	0	2	11	0	3	1	0	3	1	1	0	0	0	1
GB	16	42	15	4	1	0	0	0	0	1	2	0	0	1	0	2	0	0
EP	87	58	130	45	1	7	0	1	2	1	4	4	1	2	0	2	4	2
BE	3	16	4	6	0	3	0	0	0	0	2	0	0	1	1	0	0	0
KR	39	23	17	10	1	1	5	0	0	0	0	3	1	2	0	0	0	1
CH	0	16	2	2	0	3	0	0	0	0	4	0	0	0	0	1	0	0
IT	6	12	4	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0
AT	2	11	20	13	0	6	0	0	0	0	1	0	0	0	0	0	0	0
AU	8	39	7	7	0	5	1	0	0	0	0	1	0	2	1	0	0	0
NL	4	7	3	5	0	3	1	0	0	0	1	0	0	0	1	0	0	0
CA	20	66	10	23	0	4	2	0	0	1	1	2	1	2	0	2	0	1
SE	3	17	3	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
ES	5	12	18	22	0	7	1	0	0	0	1	3	0	0	1	0	0	0
RU	2	5	3	7	0	2	2	0	0	0	0	0	0	0	0	0	0	2
NO	11	5	3	4	0	5	1	0	0	0	0	0	0	0	1	0	0	0

Table 7: the geographical coverage of patent applications from their priority countries (horisontal axis) to their respective extension countries (vertical axis) for steel/aluminium weld

Figure 7 shows the percentage distribution of extensions from each country (e.g. the figure indicates that for cold metal transfer welding 49% of all extended applications are from USA). These pie charts can therefore indicate which priority countries are most active on extensions of the patent applications for each method.

From these charts, we also see that USA, Japan, Germany, France and Great Britain are among the top countries from which patent applications are extended. This applies for all the methods, with only some minor exceptions. For the methods cold metal transfer welding and resistance spot welding, Austria is among the top 5 extending countries alongside USA, Japan, Germany and France.

It is interesting to see that even if China, Russia and Korea are among the top countries for priority applications, these countries are almost absent from the diagram showing extension distributions. This indicates that applications first filed in these countries, are, in a lesser degree, extended to other countries or markets, as we also observe in other technical areas.

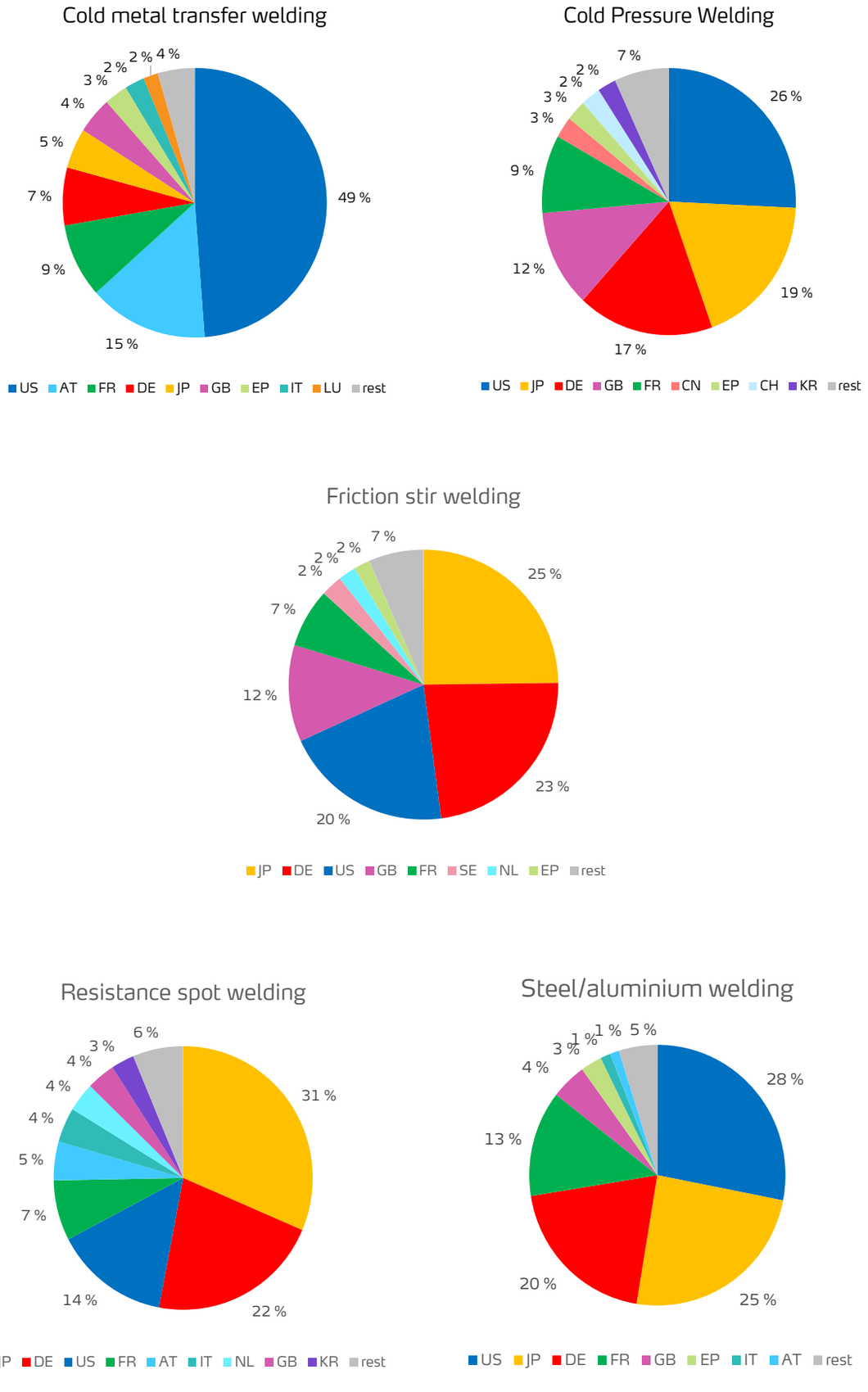
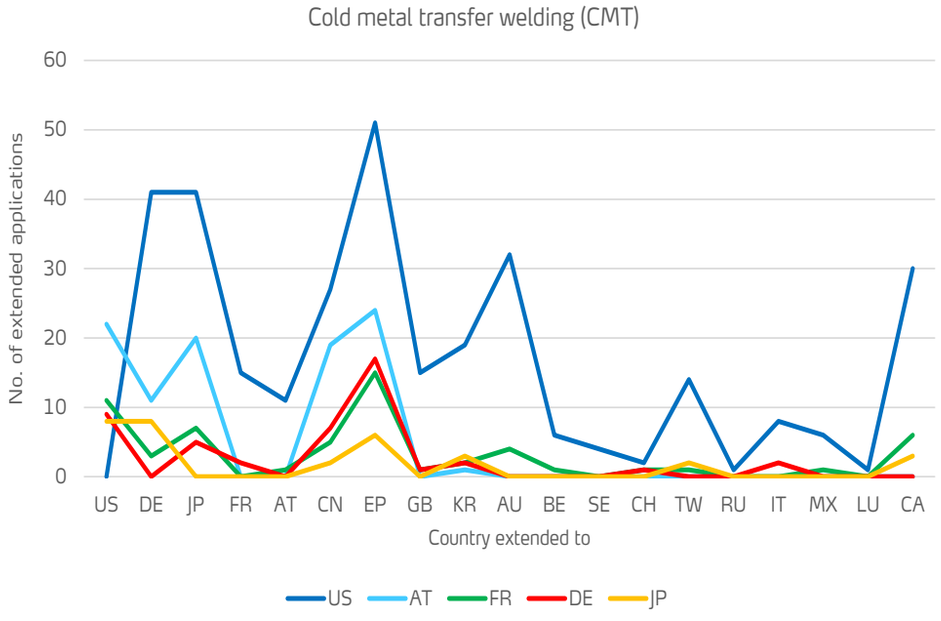


Figure 7: The distribution of the extended patent applications rated by the total number of extensions from each priority country for the different welding methods

However, Tables 3-7 and Figure 8 show that even if applications are barely extended from China, Russia and Korea, there are more applications extended to these countries from the other priority countries. This shows that patent assignees from other countries find these countries, and especially China, as important markets for their technology.

Figure 8 shows which countries the patent applications were extended to for the top 5 extending countries for each method. This indicates trends to which countries the patent applications are extended. One major trend for all the methods is that the top 5 countries all consider each other as important countries for patent application extensions. EPO (the European Patent Organisation) is also considered as important for several of the top priority countries (for all methods).

Additionally, we see that US applications are extended to Australia and Canada, British applications to Australia, Japanese applications to Taiwan, and French applications to Canada. This can indicate that language proximity and/or geographical proximity matters as well.



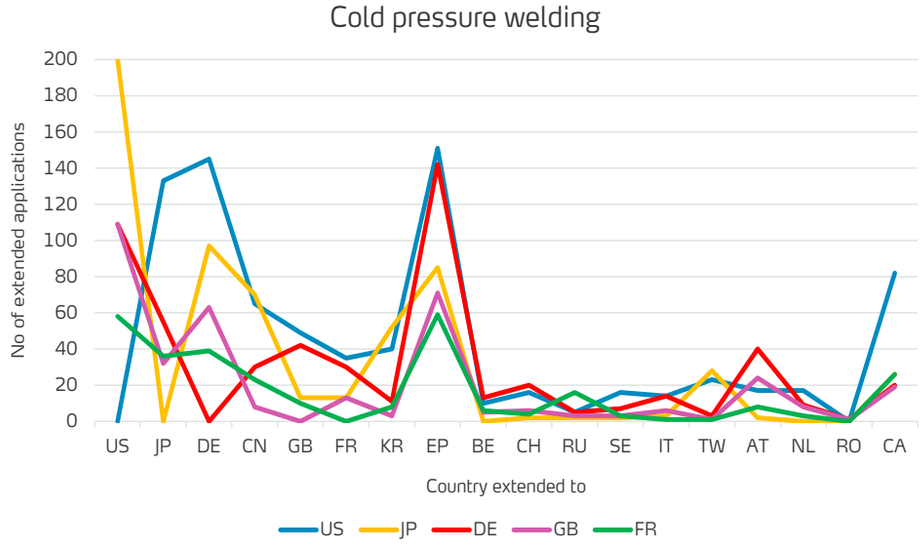
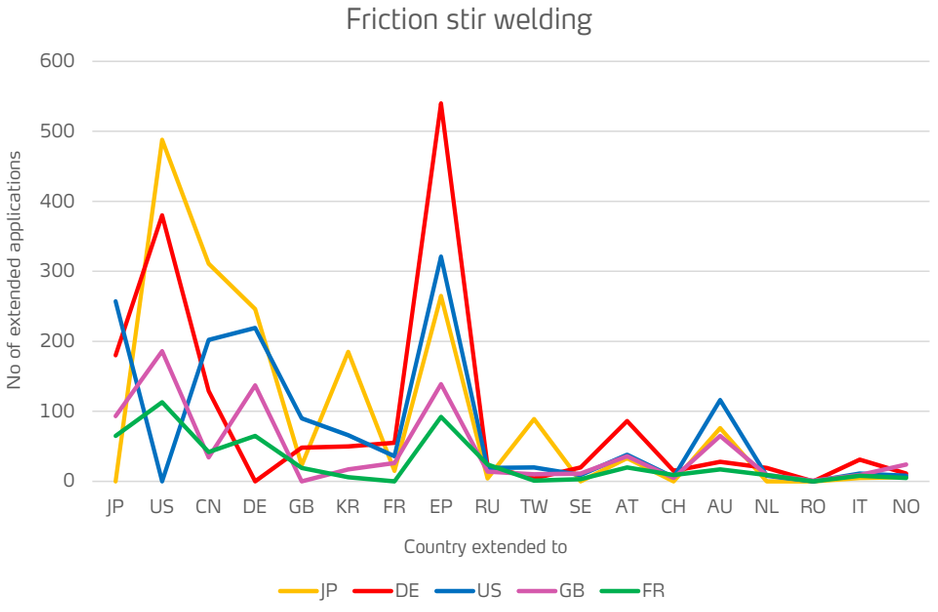
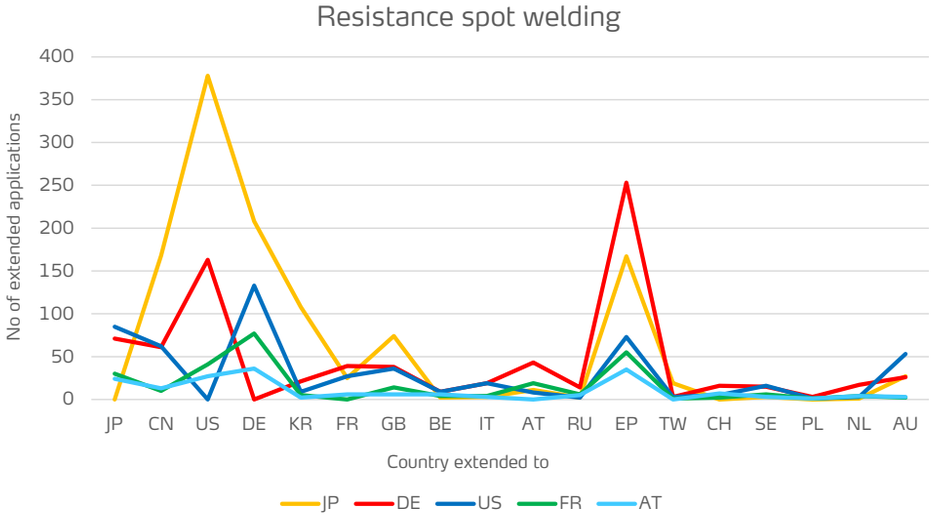


Figure 8: Countries patent applications are extended to for the top 5 countries from figure 7 (the figure continues on the following page)





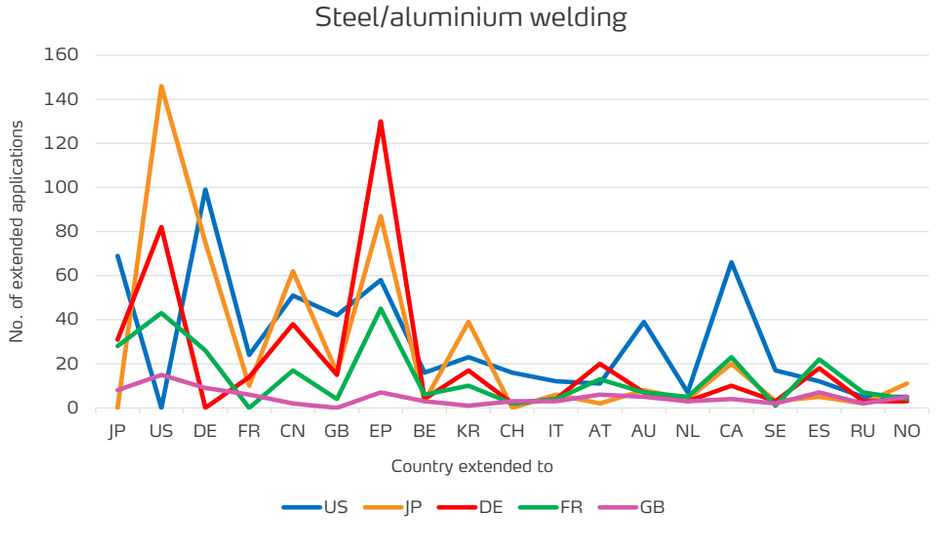


Figure 8: (the figure continues from the previous page) Countries patent applications are extended to for the top 5 countries from figure 7

Patenting in Norway

According to Figure 3, the number of patent applications first filed in Norway within metal joining as such for the years 1996-2016 is 371.

For the methods analyzed in this report, only friction stir welding and steel/aluminium welding has data on patent applications in Norway, both first filed and extended. For cold pressure welding and resistance spot welding there were registered respectively 4 and 1 priority patent applications in Norway (see tables C2 and C4 in Appendix C). These applications do not appear in the statistics over extensions, which indicate that the applications were not extended to other countries.

For the friction stir welding method there is registered 15 priority patent applications in Norway (see table C3 in Appendix C), and Table 5 shows the extension numbers. For a more detailed view on the extensions, Figure 9 shows the patent applications first filed in Norway and which country they are extended to, whereas Figure 10 shows the patent applications extended to Norway and their priority country. Comparing Figure 9 with Figure 8 (that shows extensions for the top 5 countries for the method friction stir welding), we see the same trends; the top 5 for Norwegian patent application extensions are Australia, EPO, USA, Germany and Japan. Figure 10 shows that the top priority countries also extend their applications to Norway, again with the exception of China, Russia and Korea.

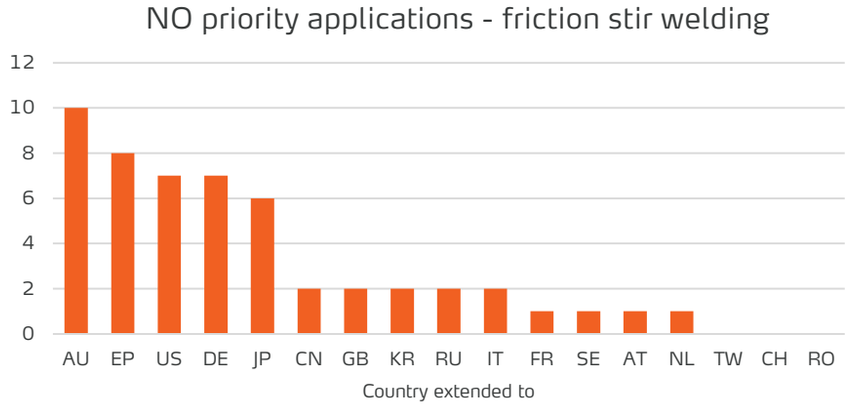


Figure 9: The patent applications first filed in Norway and which countries they are extended to.

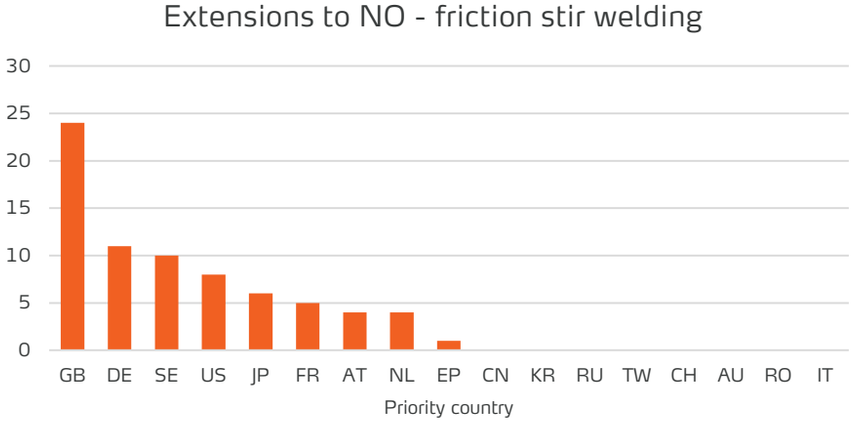


Figure 10: Patent applications extended to Norway and which country they originate from.

Likewise, for steel/aluminium welding, table C5 in Appendix C shows that there are 2 patents applications first filed in Norway, and Table 7 shows the extension numbers. For more details, see Figures 11 and 12 for respectively extensions from Norway and to Norway. Here, the numbers are too small to see obvious trends, but we can make some assumptions. Comparing Figure 11 and Figure 8 (showing extensions from the top 5 countries for steel/aluminium welding), we see that Norwegian patent applications are extended to the same countries. Figure 12 shows that the top priority countries also extend a share of their applications to Norway, with the exception of China.

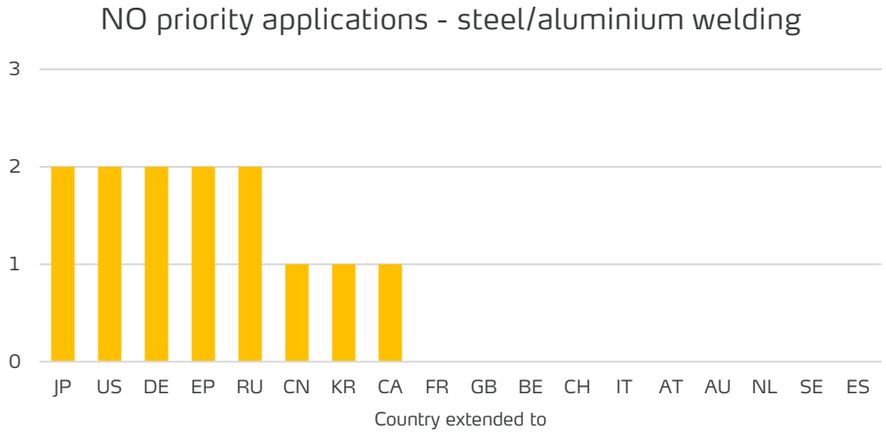


Figure 11: The patent applications first filed in Norway and which countries they are extended to.

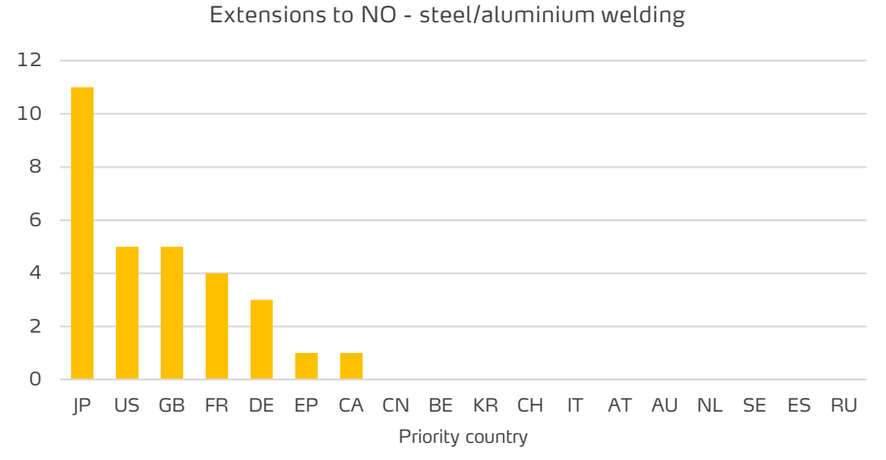


Figure 12: The patent applications extended to Norway and which country they originate from.

Trend analysis

In this chapter, we look at the patenting frequency over time for the methods in question. The number of patents per year is an indicator of the development over the years within the technological area.

An increasing number of patents implies an ongoing development within the technological area. Large increase in the number of patents from one year to another can imply an important breakthrough in the technology.

Opposite, a decreasing number of patents per year can imply that there is less development within the technology for the time being. If the decrease continues over several years, this can imply that the technology is getting old-fashioned, and that new technological areas are under development.

In this way, the development in the number of patents over the years can indicate something about the development in technology. However, there may be reasons why not all new technology is patented, therefore the number of filed patent documents do not necessarily reflect the complete picture of development.

Figure 13 shows the patenting trend for all the methods. This makes it easier to see resemblances and differences between the methods.

We see that for all the methods, the number of patent documents increase over time, especially from year 2000 and on, which indicates an increasing development within all the technologies. The total number of patent documents are quite different for the different methods, with friction stir welding and resistance spot welding being the methods with highest number of documents totally.

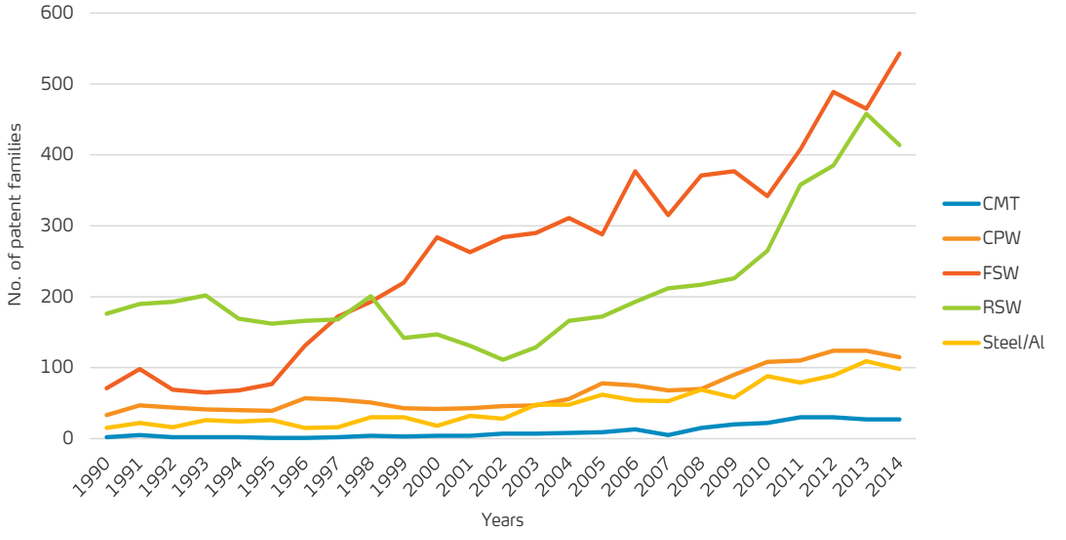


Figure 13: The patenting trends per year for all the methods together
(CMT= cold metal transfer, CPW = cold pressure welding, FSW = friction stir welding, RSW = resistance spot welding, Steel/Al = steel/aluminium welding)

Figure 14 shows the development over the years 1990-2014 for each of the welding methods.

The cold metal transfer welding method has quite a low total number of patent documents; the numbers never exceed 30 documents per year. At the same time, the growth over time is large, with less than 5 documents per year until 2002, and a growth up to 30 documents a year for 2011 and 2012. This is a relatively new method, and the low number of patent documents can indicate that protection is sought for the main technology in few, but strong patents, and that further development is ahead.

For cold pressure welding, the number of patent documents per year is relatively stable until 2003/2004, and then the number is more than doubled for the years 2009-2014, indicating an increased development the later years.

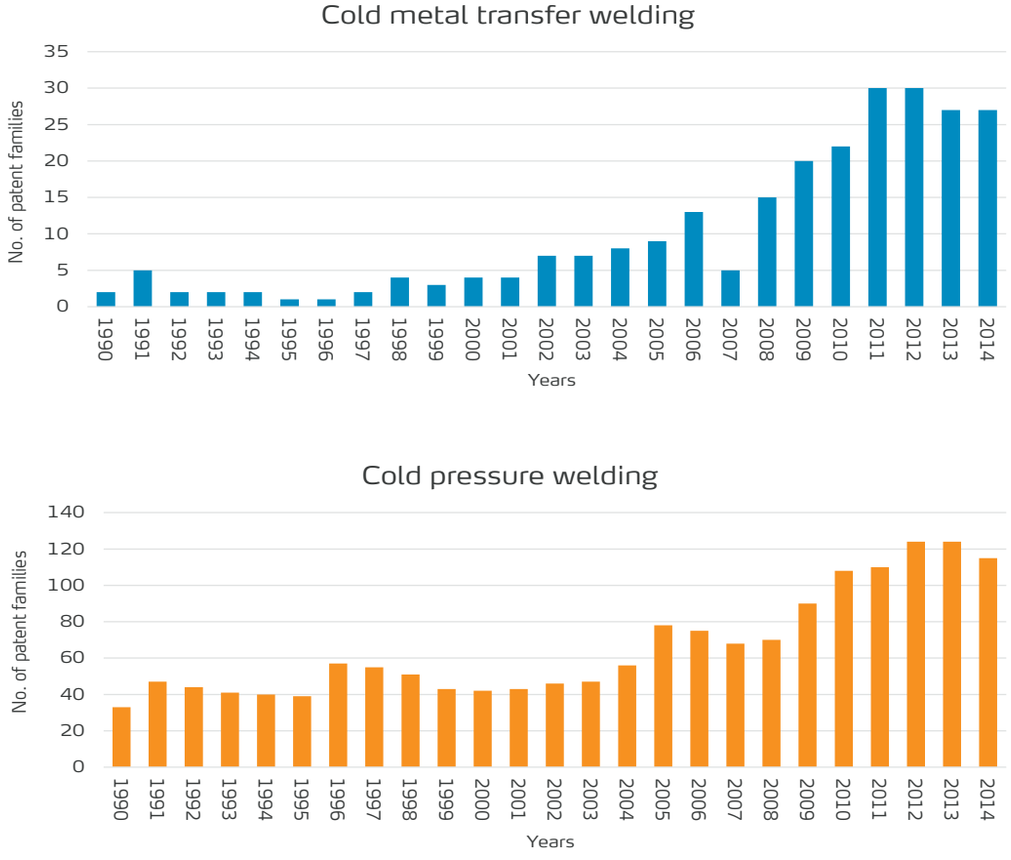


Figure 14: The patenting trend for each of the welding methods for the years 1990-2014 (the figure continues on the following page)

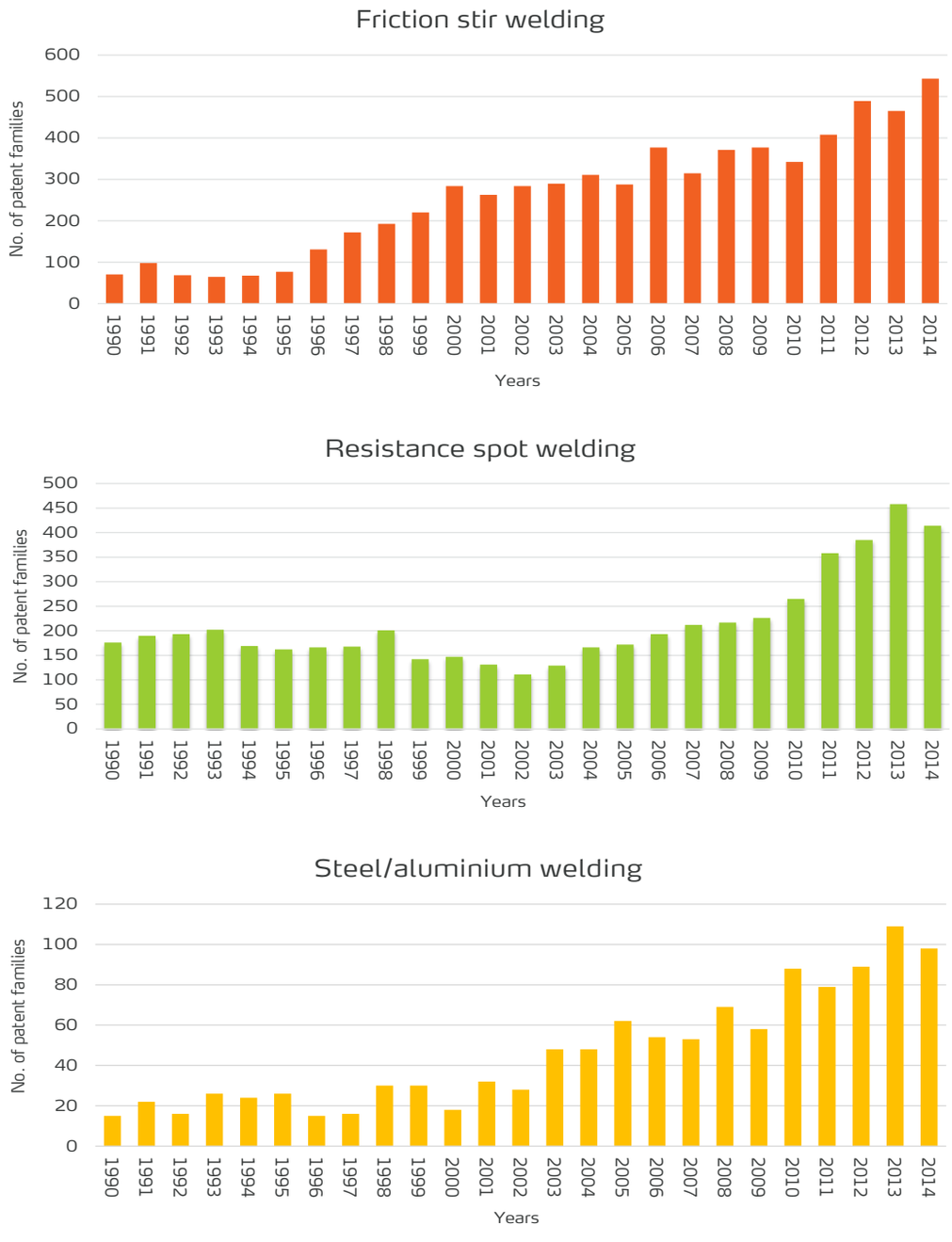


Figure 14: (the figure continues from the previous page) The patenting trend for each of the welding methods for the years 1990-2014

The friction stir welding method (including laser assisted friction stir welding) has the highest total number of patents of all the methods. The increase is also remarkable, with more than 5 times the number of documents per year for the period of 2011-2014 compared to the period of 1990-1995. This incredible increase of documents can indicate that the development is more or less based on improvement of the existing technology, and that many different actors participate in this work.

The development for the resistance spot welding method is quite similar to the other techniques, with a significant increase in patent documents per year for the period of 2011-2014.

The total number of patent documents in steel/aluminium welding is rather low, but the increase is considerably high, especially for the years 2010-2014.

The general increase in technology development for all the methods analysed in this report can contribute to explain the increase in the development for the metal joining, and especially the thermal metal joining, as shown in Figures 4 and 5 in the chapter "Overview of the technical area".

Assignee analysis

In this chapter, the patent assignees are analysed. Uncovering which assignees are dominating and whom they collaborate with may be a good basis for strategic decision making when mapping out potential collaborators or potential competitors.

A patent may have joint ownership, and can comprise one or more assignees. In this study, a patent collaboration is defined as a joint ownership of a patent. A patent collaboration may indicate a mutual interest in the commercial value of the patent, as well as other R&D work.

Most active assignees

Mapping the most active assignees within each method can be of interest to obtain information about the companies developing the methods in question. This provides information of both potential collaborators and potential competitors. However, these data sets can be difficult to get correct. Several companies are filing their patent applications under the name of the inventor rather than the company name. Therefore, the bibliographic data of the patents may not always contain the company name. Several of the larger companies also have subsidiary companies, and it can be difficult to link the subsidiary companies to the correct company name. This makes it difficult to determine the corporation of origin.

Table 8 provides an overview of the top ten patenting companies for the different methods, where the sources of errors are attempted kept at a minimum. From the list, it is apparent that several of the larger companies are among top 10 for more than one method, which is not surprising since all methods are welding methods.

Cold Metal Transfer Welding Applicant	Cold Pressure Welding Applicant	Friction Stir Welding Applicant	Resistance Spot Welding Applicant	Steel/Aluminium Weld Applicant
Lincoln Electric Global	GE (General Electric Company)	Hitachi	Honda Motor Company	NSSMC (Nippon Steel & Sumitomo Metal)
ITW (Illinois Tool Works)	Sumitomo	Nippon Light Metal Company	Toyota Motor Corporation	Exxonmobil
Fronius International	Rolls-Royce	Boeing Company	Nissan Motor Company	Kobe Steel
GSI Group Corporation	Safran Aircraft	Mitsubishi Heavy Industries	GM (General Motors Corporation)	Air Liquide
Mitsubishi Electric Corporation	Hamamatsu Photonics	Rolls-Royce	NSSMC (Nippon Steel & Sumitomo Metal)	GM (General Motors Corporation)
Presstek	Hitachi	Kawasaki Heavy Ind	Obara Corporation	Honda Motor Company
GE (General Electric Company)	United Technologies Corporation (UTC)	Showa Denko	Dengensha Manufacturing Company	Lincoln Global
Ciba-Geigy	Siemens	Sumitomo	Mazda Motor Corporation	Mazda Motor Corporation
Meidensha Corporation	Byd Company	GE (General Electric Company)	Hyundai Group	Dana Corporation
Safran Aircraft	Boeing Company	Airbus	Kobe Steel	Alcoa (Aluminum Company Of America)/Nissan Motor Company

Table 8: The top 10 assignees for the different technical area

Figures 15-19 show the yearly distribution and the IPC distribution, respectively, for the top 10 companies within the different welding methods. There may be differences in which companies are top 10 in the table and the figures showing the yearly and IPC distribution. This is due to the fact that in the list in Table 8, the errors previously mentioned is taken into consideration. As for the Figures 15-19, this correction was not possible to the same extent.

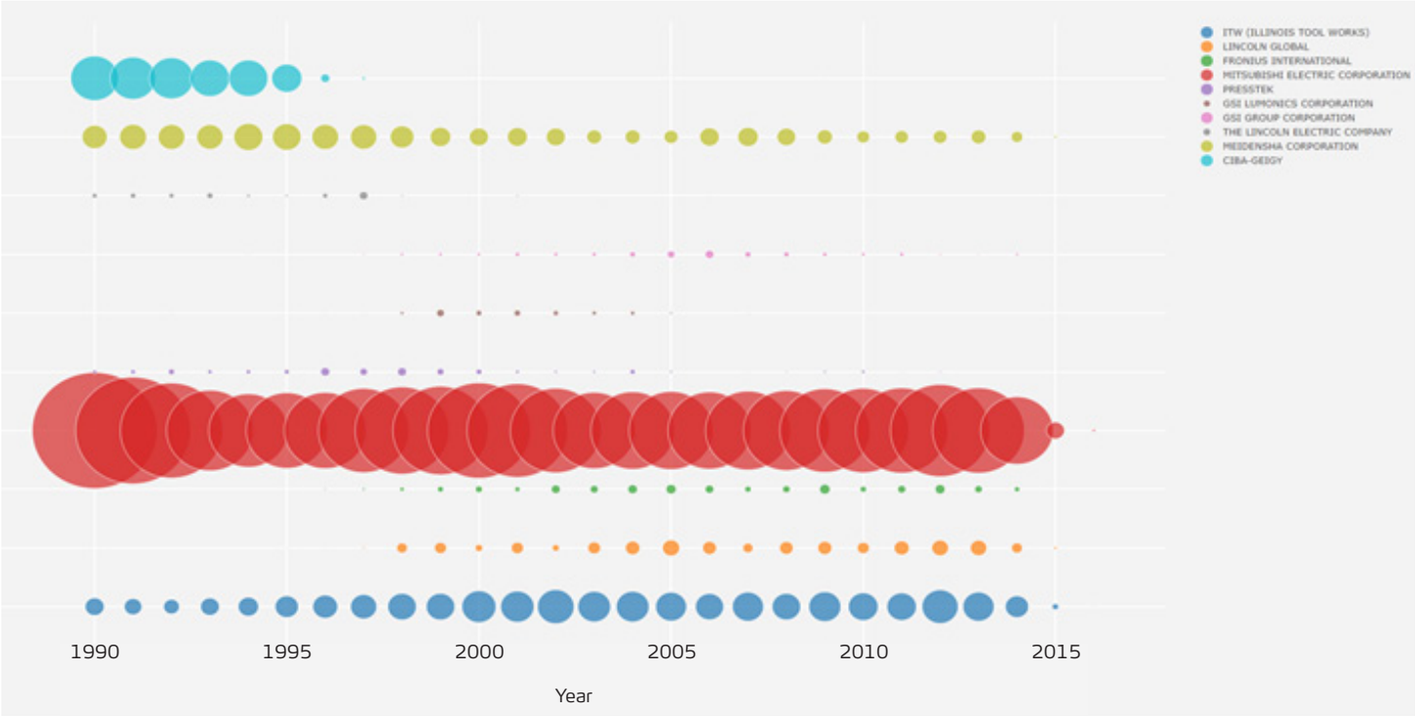
The yearly distribution can say something about the patenting frequency of the companies for the years 1990-2015. This shows whether the companies are active in innovation throughout the years, and if the activity increases or decreases.

For the welding techniques in this report, almost all the top companies are active throughout the period. The exceptions are largely due to change in company names or merging of companies.

The IPC distribution (for definition and explanation of IPC, see the glossary at the end of the report) reveals something about the technology field in which the companies are active. It shows whether the companies operate within several technical areas, or if they focus solely on welding technology. The main IPC class for welding is B23, as shown in Table 2.

Several of the companies in the Figures 15-19 are active within many technical areas. Mitsubishi Electric and Hitachi have their main technology within electronics, whereas Honda, Toyota and Mazda motor companies have their main technology within cars and motors. Nippon Steel (later Nippon Steel and Sumitomo Metal) and Kobe Steel both have metals and metalworking as main technologies. The companies Fronius International (Cold Metal Transfer Welding), Obara Corporation and Dengensha Manufacturing Company (Resistance Spot Welding) have their activity solely within the welding technology.

Cold metal transfer welding



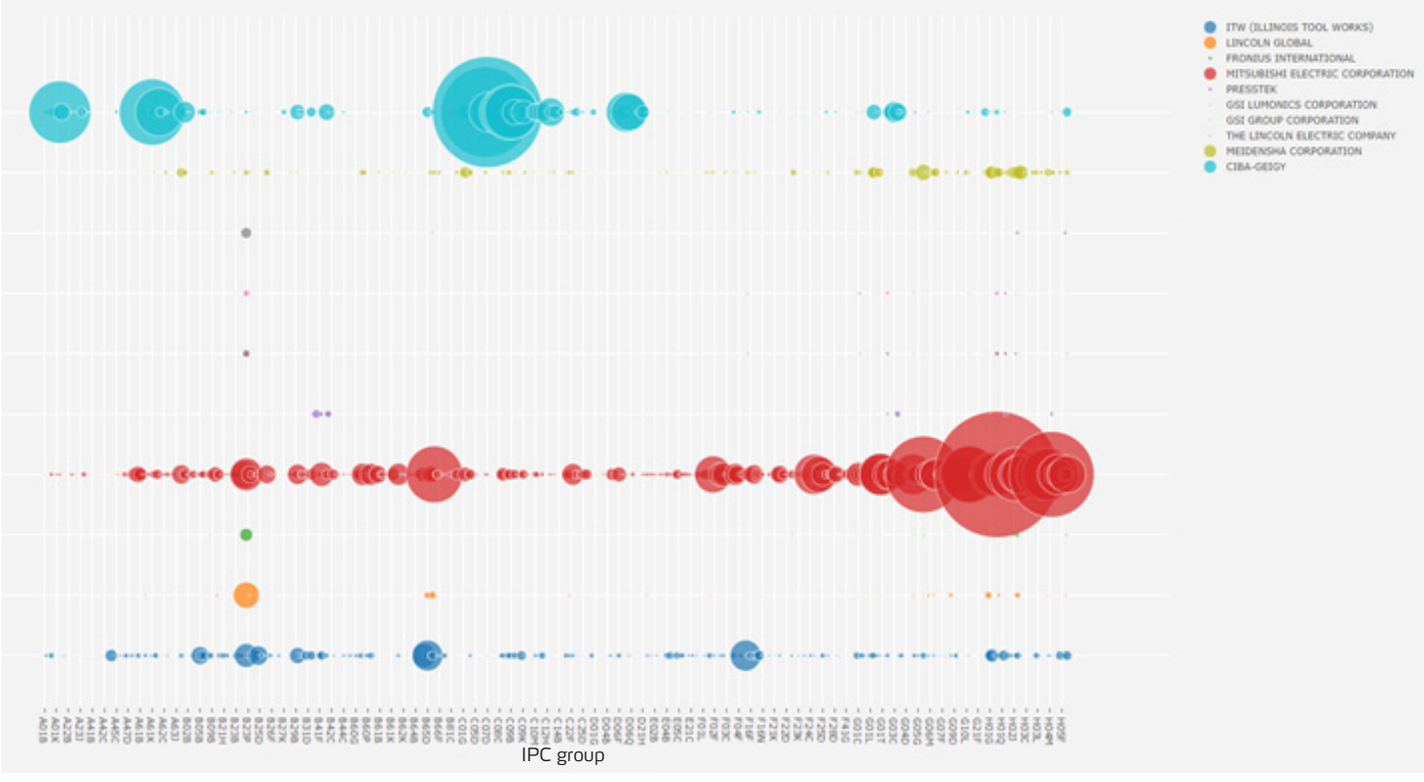


Figure 15: Yearly and IPC distribution respectively for the top 10 companies for the cold metal transfer welding method.

Cold pressure welding

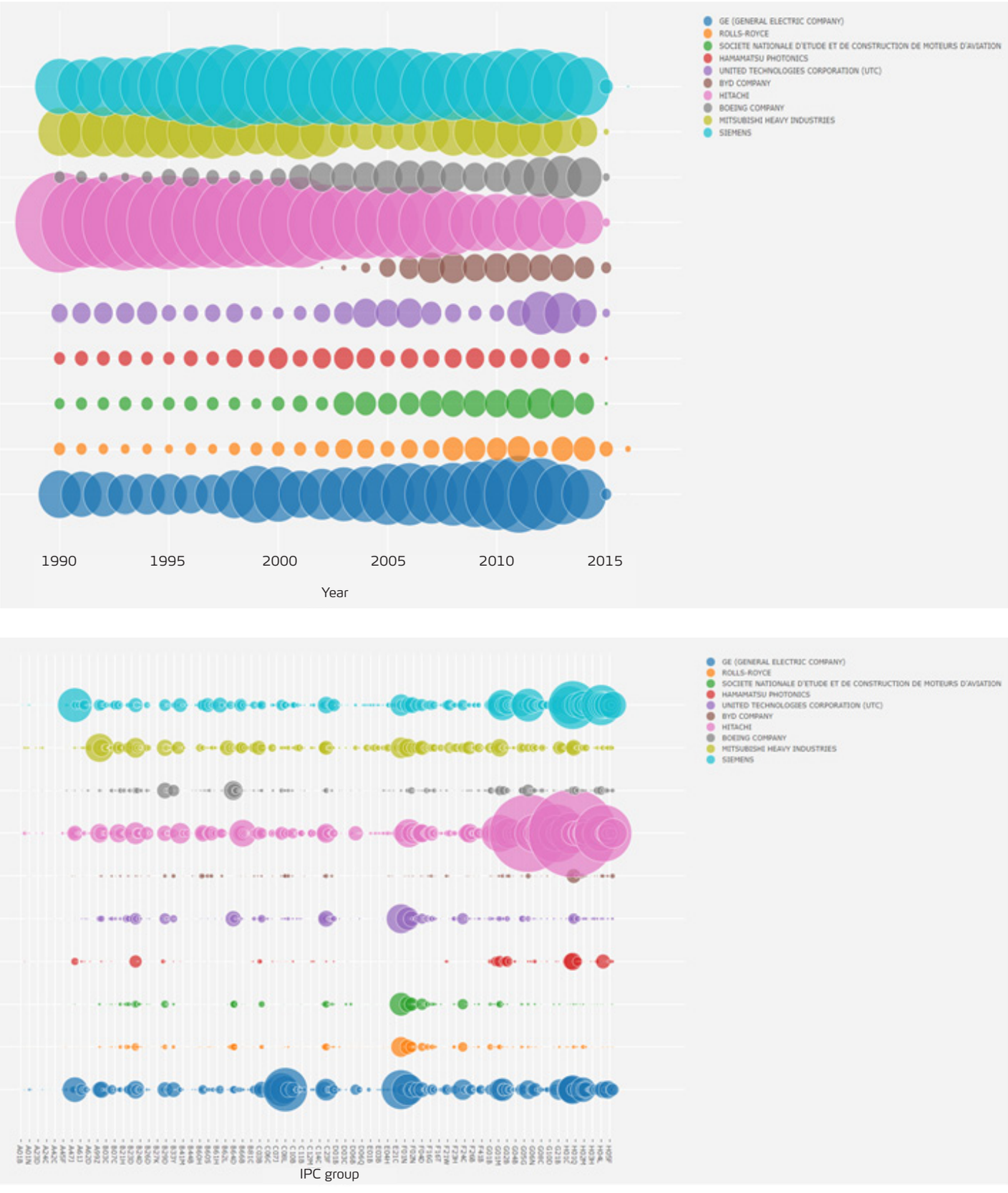


Figure 16: Yearly and IPC distribution respectively for the top 10 companies for the cold pressure welding method.

Friction stir welding

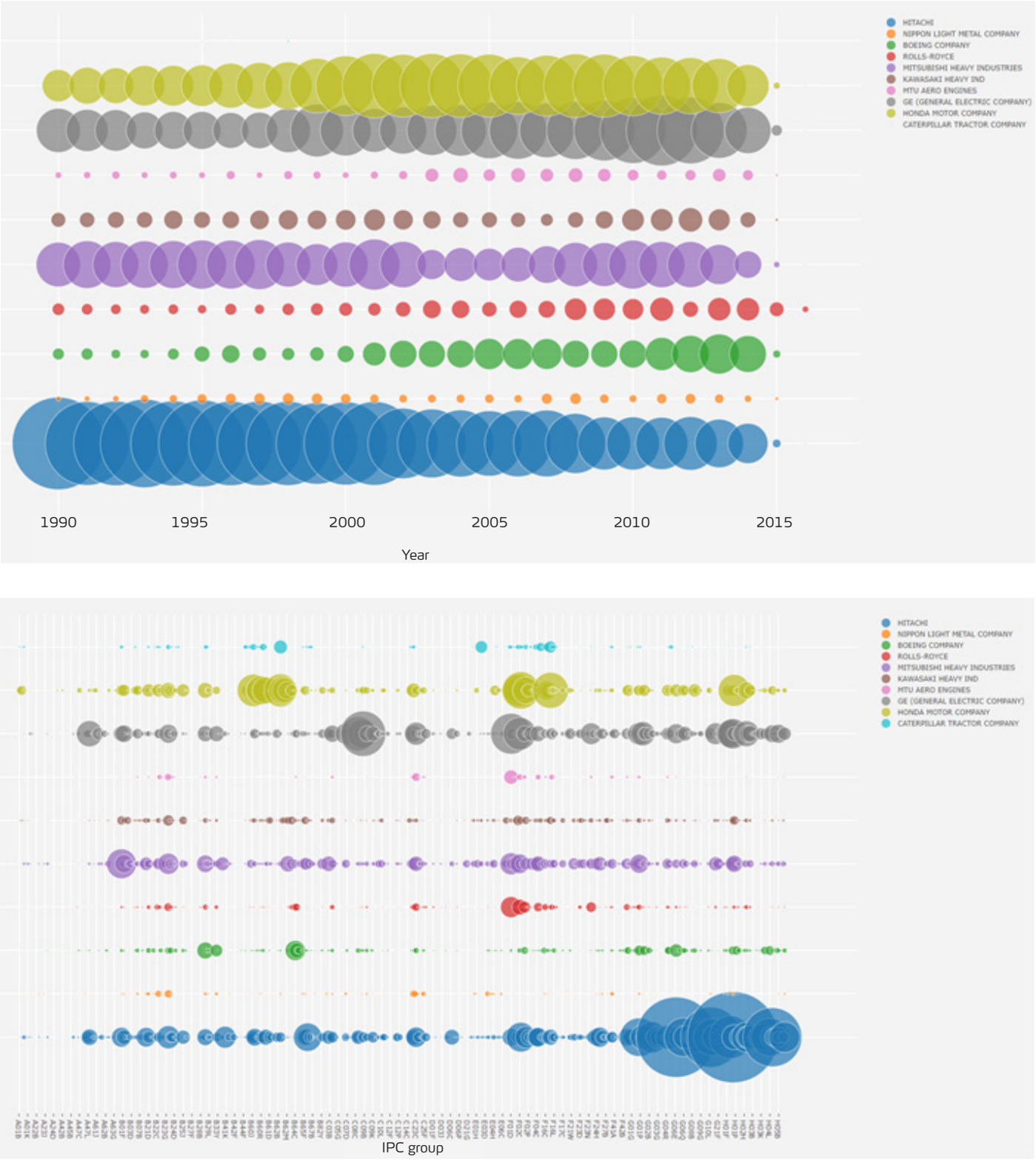
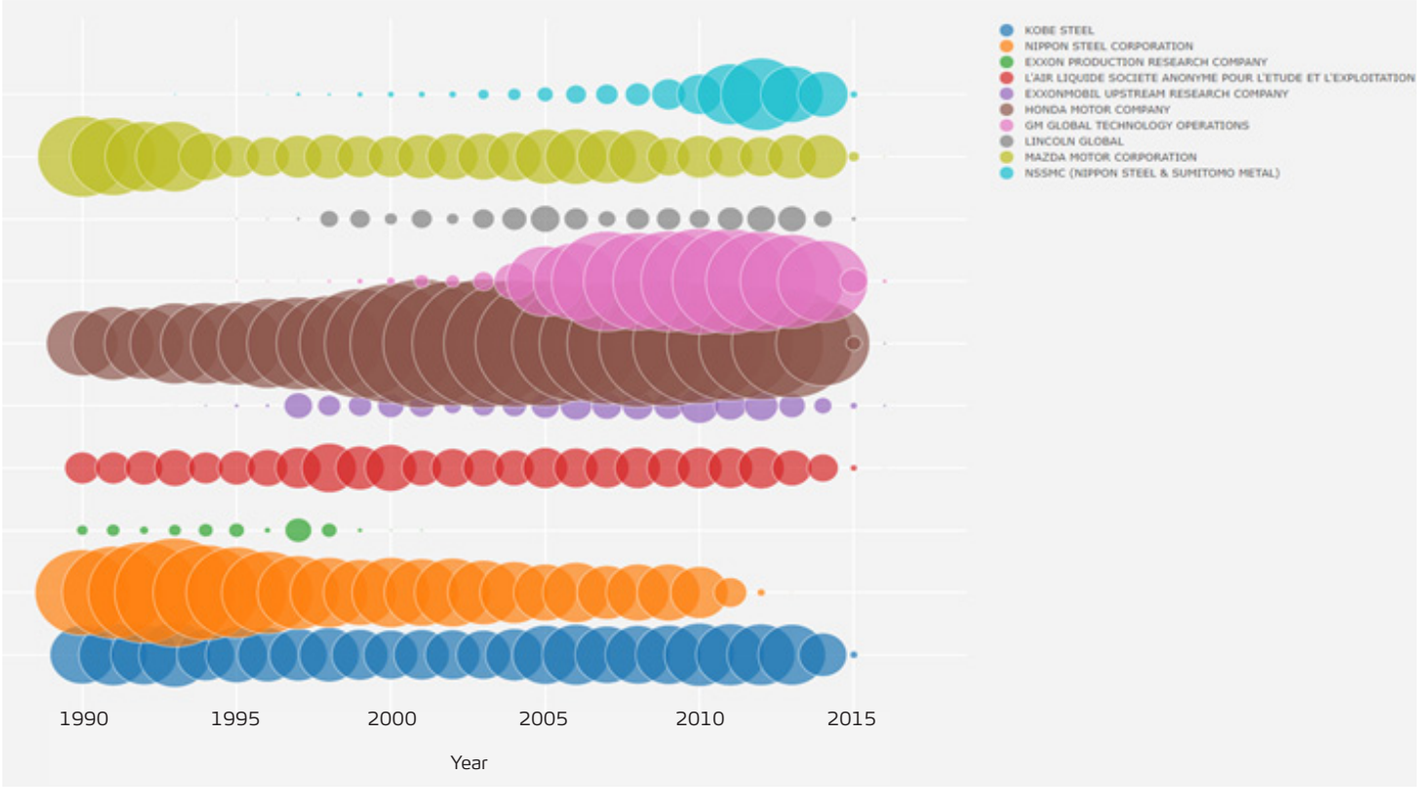


Figure 17: Yearly and IPC distribution respectively for the top 10 companies for the friction stir welding method

Resistant spot welding

Figure 18: Yearly and IPC distribution respectively for the top 10 companies for the resistance spot welding method.

Steel/aluminium welding



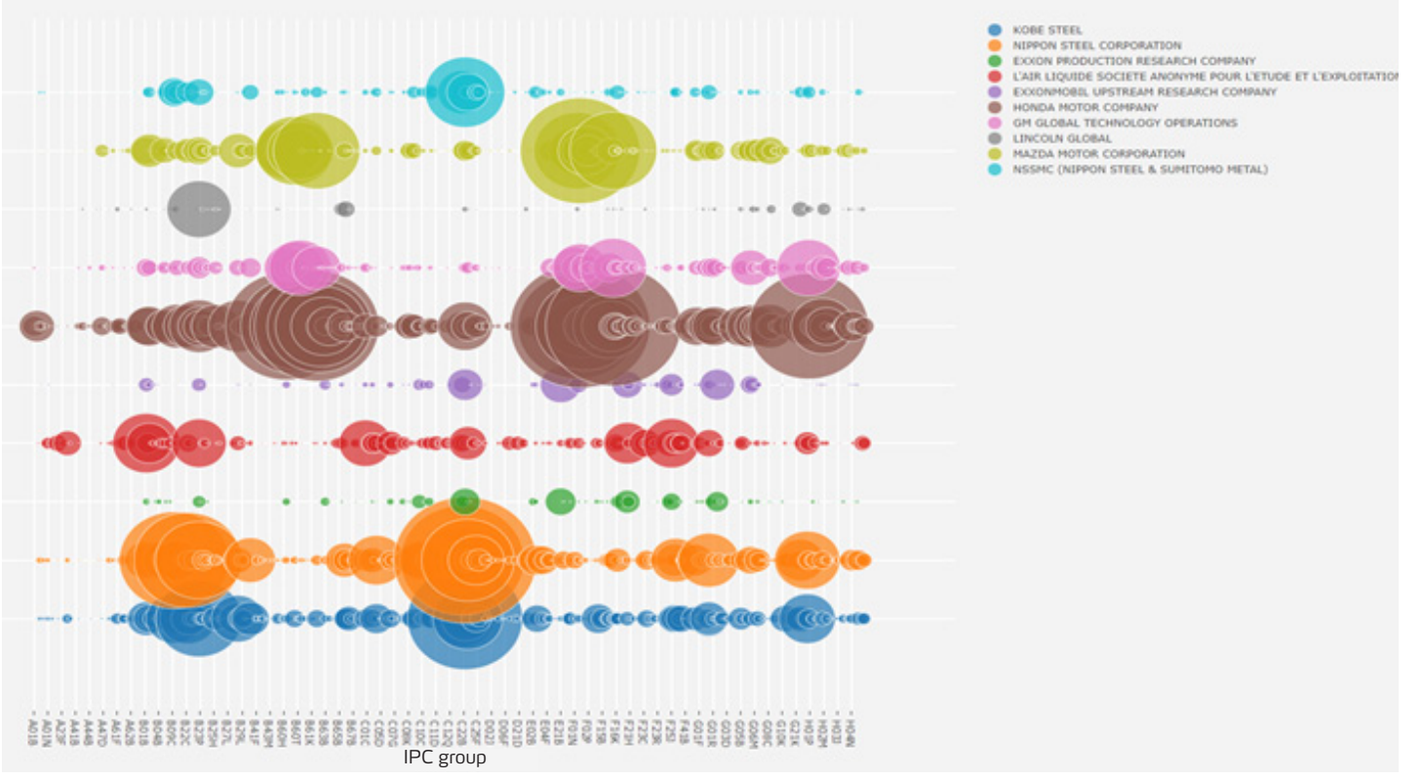


Figure 19: Yearly and IPC distribution respectively for the top 10 companies for the steel/aluminium welding method

Collaboration networks

Information of patent collaborations reveals important information of the top companies within a technological area, as this can provide information of collaboration networks.

Patent collaborations can be illustrated in several ways, but for complex collaboration networks, a graphical representation is often preferred. In this context, the term collaboration map is used as a graphical presentation of several collaboration networks.

There are many collaboration networks between assignees in this patent data set. Some of the larger collaboration networks for each of the methods are depicted in Figure 20.

The figure shows that some collaboration networks are large, whereas others are rather small. Some of the collaboration networks also contain subsidiary companies, which is natural. Several of the top 10 companies collaborate with each other as well, especially among the Japanese companies (see the resistance spot welding method collaborators as an example).

Studying the collaboration networks of the companies within the technology field can give useful information of the companies as either potential collaborators or competitors.

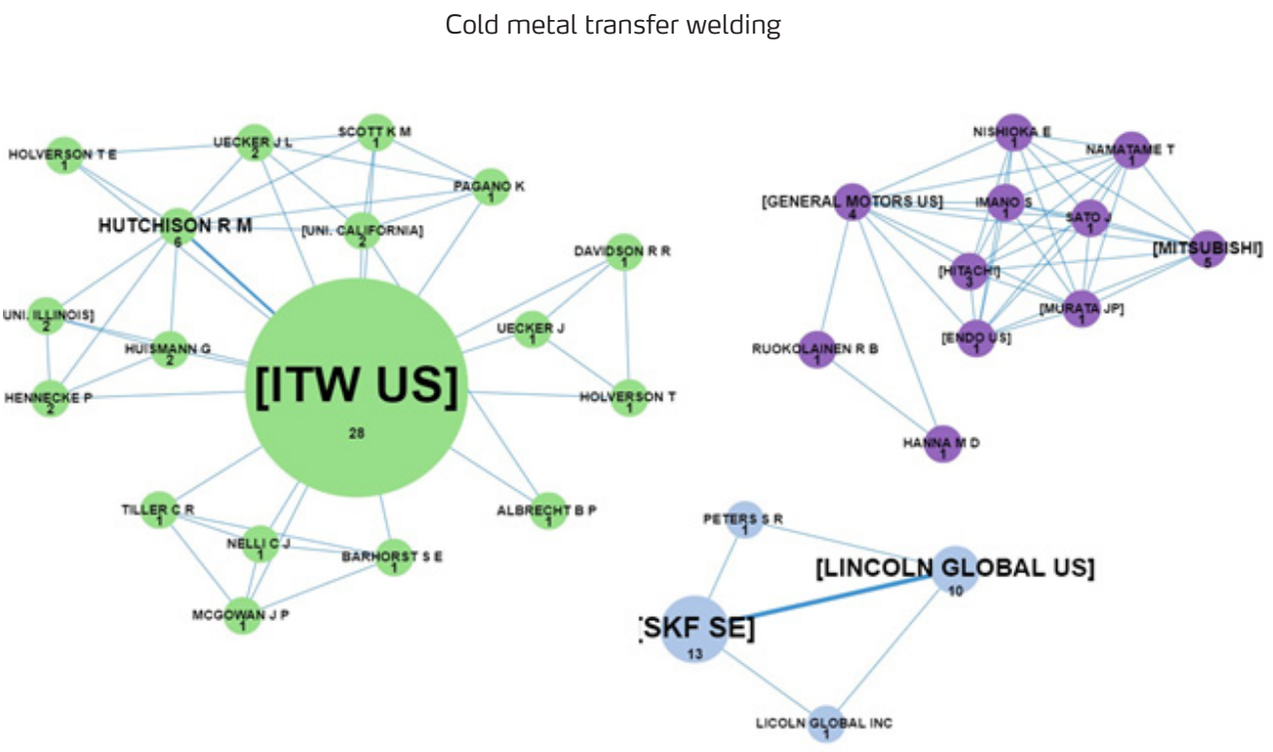
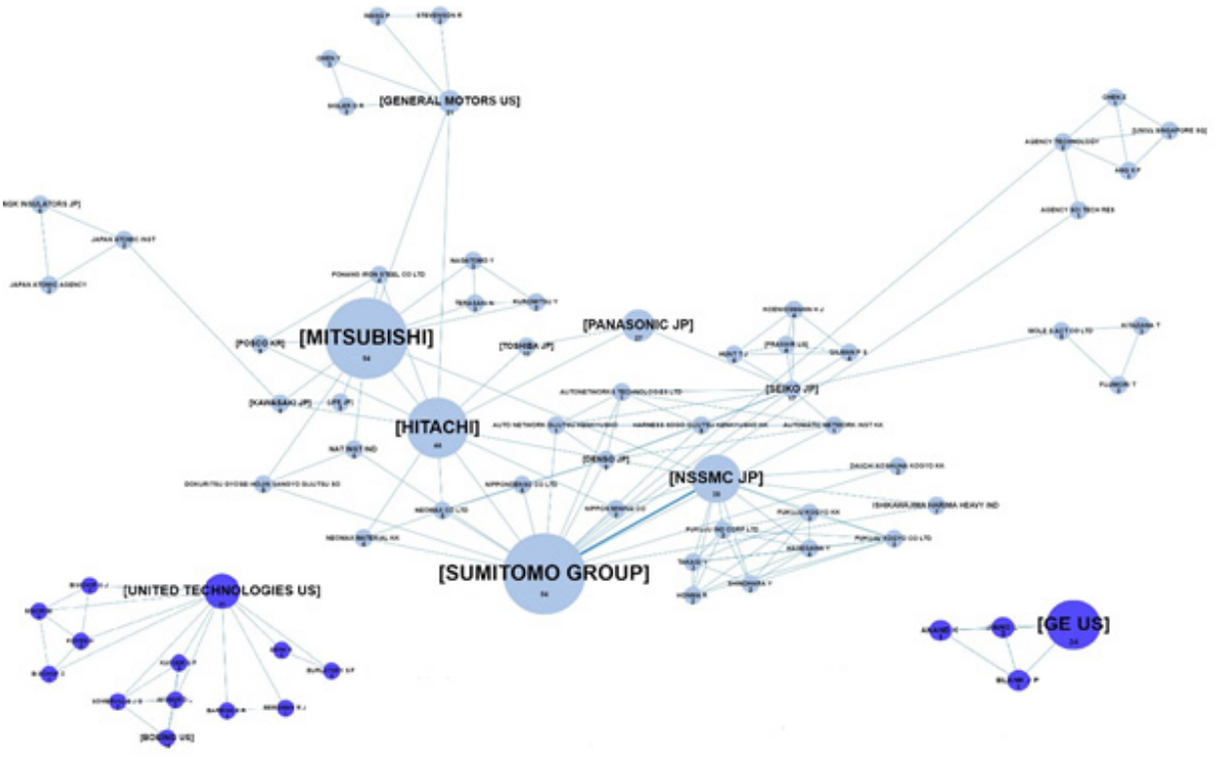


Figure 20: Some of the collaboration networks for each of the welding methods in this report (the figure continues on the following page)

Cold pressure welding



Friction stir welding

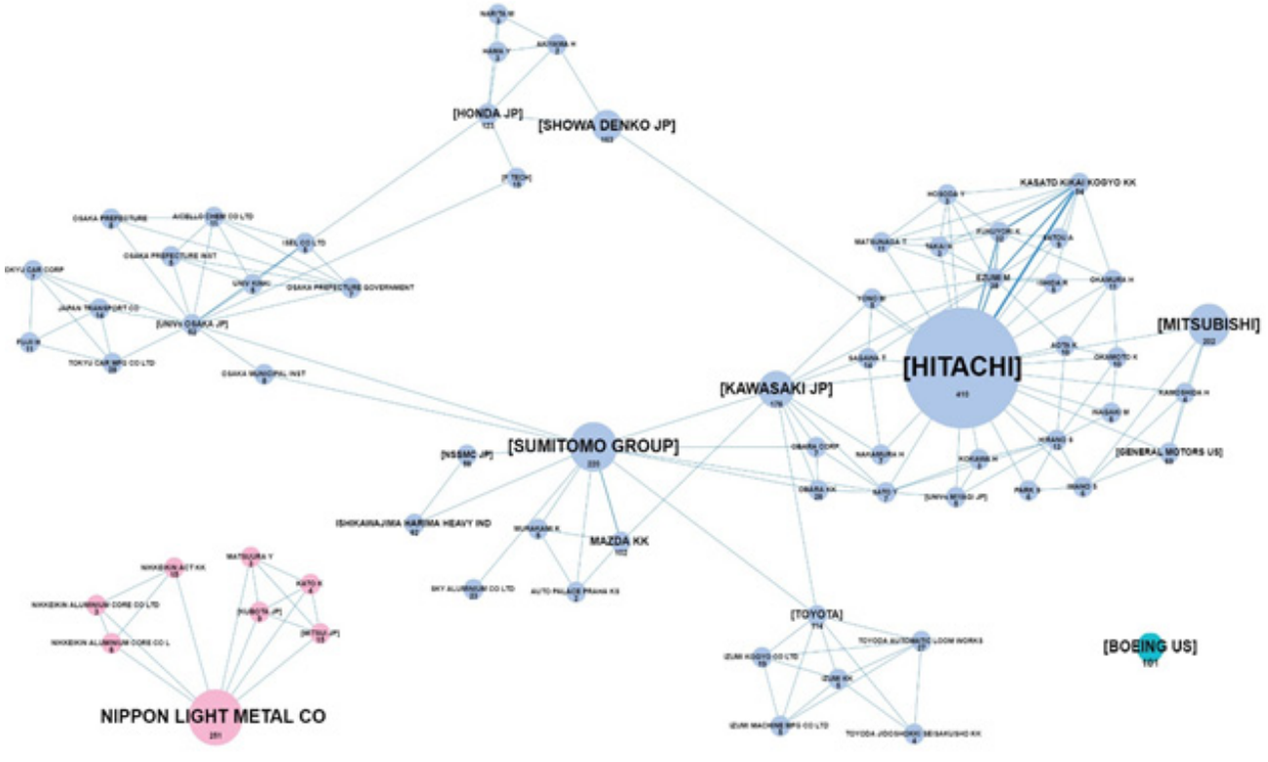
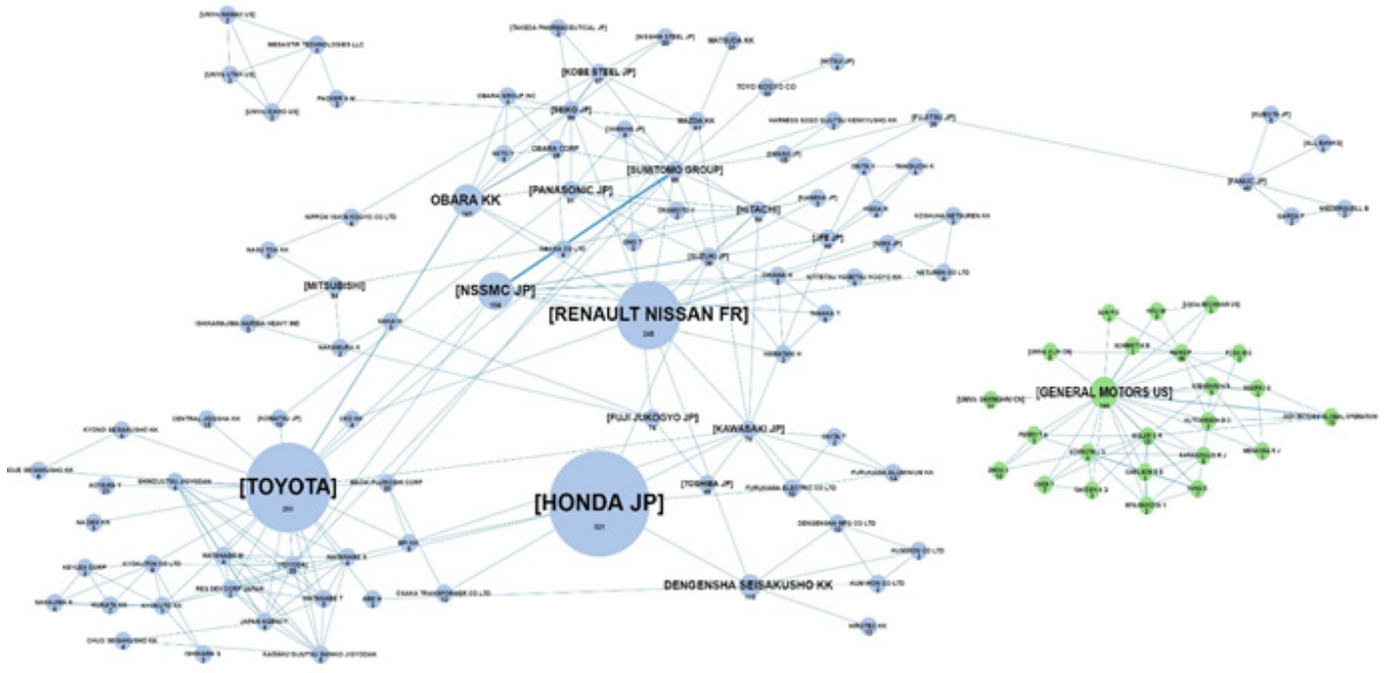


Figure 20: (the figure continues from the following page) Some of the collaboration networks for each of the welding methods in this report (the figure continues on the following page)

Resistant spot welding



Steel/aluminium welding

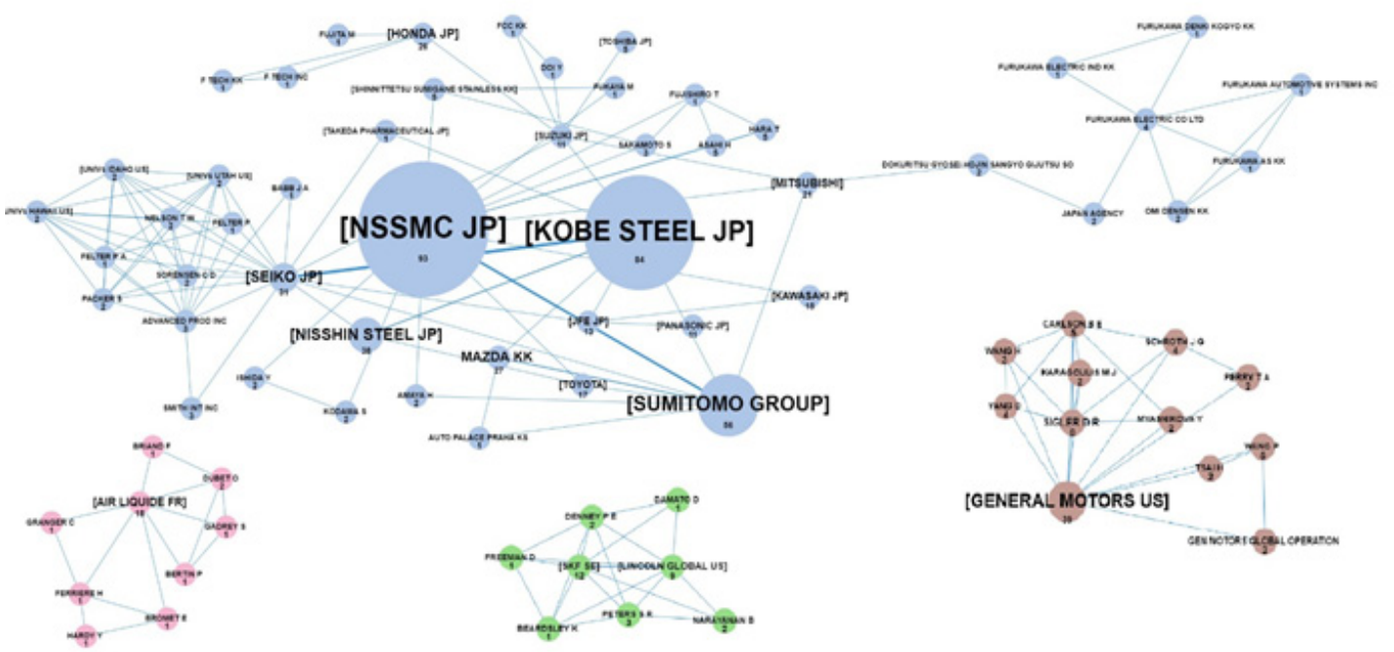


Figure 20: (the figure continues from the following page) Some of the collaboration networks for each of the welding methods in this report.

Observations

The following observations are found throughout the report, and restated here for easy reference. This landscape analysis started with a large number of patent documents in joining technology (673 300 patent documents). A patent data set of this magnitude is too large to provide a good analysis of the data, therefore five different metal welding techniques were chosen for the analysis. The five sub data sets will also be too large to be completely accurate. However, the data sets may give a good indication of the patenting development for the technologies in question.

- Even if metal joining is an ancient technology, the figures show that it is still under development. The figures showing the patenting development of polymer joining and the newer technology of additive manufacturing also show an ever increasing number of patent documents per year. This indicates that there is an increasing innovation in the joining technology as such.

- The figures on the five welding techniques in question show the same trend, there are increasing number of patents per year for all the methods.

- The top priority countries for both metal and polymer joining, as well as for additive manufacturing, are USA, Japan, Germany and China.

- USA, Japan, Germany and China are also among the top priority countries for all the welding methods. France, Great Britain, Russia and Korea are likewise important countries with high filing rates for several of the welding methods.

- All the top priority countries extend their patent applications to the other top priority countries, with the exception of China, Korea and Russia, as we also observe within other technological areas.

- The patenting rate in Norway is low compared to the other countries. The total number of patent documents first filed in Norway within metal joining is 371 (for the years 1996-2016). In our dataset, friction stir welding and steel/aluminium welding are the only two methods providing data on extensions in Norway.

- However, it is interesting to see that the same trends apply in Norway as the other priority countries when it comes to where the applications are extended to; USA, Japan, Germany and EPO. As for applications extended to Norway, the top priority countries also regard Norway as a market, again with the exception of China, Korea and Russia.

- Data on the top patent assignees show that many of the companies are among top 10 for several of the welding methods. Some of the top companies are active in several areas, comprising a large span of technology, while others have their main activity within the welding technology.

- The collaboration networks for the companies in this report are of varying size. Especially the Japanese companies have large networks, both with other companies and with their own subsidiary companies.

Glossary of Intellectual Property related terms

This IPR terminology contains basic expressions used that are frequently used within IPR analysis, mainly those IPRs concerning patents.

IPR: Intellectual Property Rights, exclusive rights protecting inventions, names, logos, design and other innovations.

Invention: A new device, composition or process. To be patentable, the invention has to be a practical solution of a problem, where the solution has a technical characteristic, a technical effect and is reproducible.

Patent: Protection of a concrete solution of a technical problem, an invention.

Patent application: A request pending at a patent office for grant of a patent for the invention described and claimed in the application.

Priority: If several assignees file a patent application for the same invention, the assignee who was the first to file will achieve the patent right. The assignee, who filed an application in a country, can claim priority in other countries of interest. This right is valid in 12 months from the day of filing in the first country - the priority day. The priority implies that the assignee has a precedence to others who have filed a patent application on the same invention after the priority date.

Patent publication: A broad term, comprising both granted patent applications and pending patent applications. All patent applications are published, and therefore made public, within 18 moths after filing date, unless the patent application is withdrawn by the applicant.

Patent family: A collection of applications and patents concerning the same invention worldwide. This means that at patent family includes all documents (patent applications and patents) with exactly the same priority, including the initial priority application and all the subsequent applications worldwide.

Prior art: All information that has been made available to the public in any form before the priority date. Anything can be prior art.

EPO: The European Patent Office receives, examines and makes decisions of European patent applications according to the rules in the European Patent Convention (EPC).

Patent office: A governmental or intergovernmental organization controlling the issue of patents.

Patent kind code: A code system indicating the status of a patent document. Patent documents often retain the same identification number throughout the application process, and this code indicates whether the document is still an application, a granted patent, a utility model, etc.

Patent extension: Filing of patent application to further countries, either directly to each national government or through international or regional organizations that simplifies the application process, e.g. through PCT or EPO.

Patent classification: There are two main classification systems for patents, IPC (International Patent Classifications) and CPC (Cooperative Patent Classification). The CPC system is the newest and contains both the IPC-classes as well as more detailed classes (see worldwide.espacenet.com/classification).

Utility model: An intellectual property right to protect inventions available in a number of countries. It is very similar to a patent, but usually has a shorter term of protection (6 to 15 years) and less stringent patentability requirements.

PCT: Patent Cooperation Treaty is a worldwide convention of patent cooperation that simplifies the process to apply for patents in other countries.

WIPO: World Intellectual Property Organization is one of UN's special organizations with 188 member states. The main aim is to encourage the global development of IPR.

IPC Classification: International Patent Classification is a classification system that makes it possible to find the information of importance for the examination. All patent applications filed to NIPO are classified according to IPC.

CPC classification: Cooperative Patent Classification is mainly based on the IPC classification system, but contains more subgroups than IPC and hence makes it possible to classify more detailed than IPC. NIPO has been using CPC for classification of patent applications since October 2015, this in addition to the IPC classification system.

Appendix A

PCT Contracting States and Two-letter Codes

(the list is retrieved from http://www.wipo.int/export/sites/www/pct/en/list_states.pdf)

AE	United Arab Emirates	CU	Cuba	IL	Israel	MG	Madagascar	SD	Sudan (AP)
AG	Antigua and Barbuda	CY	Cyprus (EP)[2]	IN	India	MK	The former Yugoslav Republic of Macedonia (EP)	SE	Sweden (EP)
AL	Albania (EP)	CZ	Czechia (EP)	IR	Iran (Islamic Republic of)	ML	Mali (OA)[2]	SG	Singapore
AM	Armenia (EA)	DE	Germany (EP)	IS	Iceland (EP)	MN	Mongolia	SI	Slovenia (EP)[2]
AO	Angola	DJ	Djibouti	IT	Italy (EP)[2]	MR	Mauritania (OA)[2]	SK	Slovakia (EP)
AT	Austria (EP)	DK	Denmark (EP)	JO	Jordan	MT	Malta (EP)[2]	SL	Sierra Leone (AP)
AU	Australia	DM	Dominica	JP	Japan	MW	Malawi (AP)	SM	San Marino (EP)
AZ	Azerbaijan (EA)	DO	Dominican Republic	KE	Kenya (AP)	MX	Mexico	SN	Senegal (OA)[2]
BA	Bosnia and Herzegovina	DZ	Algeria	KG	Kyrgyzstan (EA)	MY	Malaysia	ST	Sao Tome and Principe (AP)
BB	Barbados	EC	Ecuador	KH	Cambodia[3]	MZ	Mozambique (AP)	SV	El Salvador
BE	Belgium (EP)	EE	Estonia (EP)	KM	Comoros (OA)2	NA	Namibia (AP)	SY	Syrian Arab Republic
BF	Burkina Faso (OA)	EG	Egypt	KN	Saint Kitts and Nevis	NE	Niger (OA)[2]	SZ	Swaziland (AP)[2]
BG	Bulgaria (EP)	ES	Spain (EP)	KP	Democratic People's Republic of Korea	NG	Nigeria	TD	Chad (OA)[2]
BH	Bahrain	FI	Finland (EP)	KR	Republic of Korea	NI	Nicaragua	TG	Togo (OA)[2]
BJ	Benin (OA)	FR	France (EP)[2]	KW	Kuwait	NL	Netherlands (EP)[2]	TH	Thailand
BN	Brunei Darussalam	GA	Gabon (OA)[2]	KZ	Kazakhstan (EA)	NO	Norway (EP)	TJ	Tajikistan (EA)
BR	Brazil	GB	United Kingdom (EP)	LA	Lao People's Democratic Republic	NZ	New Zealand	TM	Turkmenistan (EA)
BW	Botswana (AP)	GD	Grenada	LC	Saint Lucia	OM	Oman	TN	Tunisia[6]
BY	Belarus (EA)	GE	Georgia	LI	Liechtenstein (EP)	PA	Panama	TR	Turkey (EP)
BZ	Belize	GH	Ghana (AP)	LK	Sri Lanka	PE	Peru	TT	Trinidad and Tobago
CA	Canada	GM	Gambia (AP)	LR	Liberia (AP)	PG	Papua New Guinea	TZ	United Republic of Tanzania (AP)
CF	Central African Republic (OA)	GN	Guinea (OA)[2]	LS	Lesotho (AP)	PH	Philippines	UA	Ukraine
CG	Congo (OA)	GQ	Equatorial Guinea (OA)[2]	LT	Lithuania (EP)[2]	PL	Poland (EP)	UG	Uganda (AP)
CH	Switzerland (EP)	GR	Greece (EP)[2]	LU	Luxembourg (EP)	PT	Portugal (EP)	US	United States of America
CI	Côte d'Ivoire (OA)	GT	Guatemala	LV	Latvia (EP)[2]	QA	Qatar	UZ	Uzbekistan
CL	Chile	GW	Guinea-Bissau (OA)[2]	LY	Libya	RO	Romania (EP)	VC	Saint Vincent and the Grenadines
CM	Cameroon (OA)	HN	Honduras	MA	Morocco4	RS	Serbia (EP)	VN	Viet Nam
CN	China	HR	Croatia (EP)	MC	Monaco (EP)[2]	RU	Russian Federation (EA)	ZA	South Africa
CO	Colombia	HU	Hungary (EP)	MD	Republic of Moldova[5]	RW	Rwanda (AP)	ZM	Zambia (AP)
CR	Costa Rica	ID	Indonesia	ME	Montenegro[1]	SA	Saudi Arabia	ZW	Zimbabwe (AP)
		IE	Ireland (EP)[2]			SC	Seychelles		

Table A1: PCT contracting states and two-letter codes

1 Extension of European patent possible.
2 May only be designated for a regional patent (the "national route" via the PCT has been closed).
3 Validation of European patent possible for international applications filed on or after 1 March 2018.
4 Validation of European patent possible.
5 Validation of European patent possible for international applications filed on or after 1 November 2015.
6 Validation of European patent possible for international applications filed on or after 1 December 2017.

Where a State can be designated for a regional patent, the two-letter code for the regional patent concerned is indicated in parentheses (AP = ARIPO patent, EA = Eurasian patent, EP = European patent, OA = OAPI patent).

Appendix B

Tables with number of patent documents per country for all the joining methods

Country code	No. of patent documents
US	78256
JP	67372
WO	64446
DE	34050
CN	33641
EP	10230
FR	9730
KR	9029
GB	6508
SE	2184
TW	1780
AT	1751
AU	1427
FI	980
CA	949
DK	495
NO	371

Table B1: The number of patent documents for metal joining (Figure 3)

Country code	No. of patent documents
US	43247
JP	31353
DE	18967
EP	8313
CN	7249
FR	4907
GB	4390
WO	4078
KR	3298
SE	1729
AU	932
TW	910
FI	568
CA	563
AT	508
DK	477
NO	154

Table B2: The number of patent documents for polymer joining (Figure 3)

Country code	No. of patent documents
US	8143
WO	5855
DE	3139
CN	2705
JP	1974
EP	1278
GB	913
FR	662
TW	273
KR	265
AU	163
SE	142
DK	74
AT	65
CA	28
NO	3
FI	1

Table B3: The number of patent documents for additive manufacturing (Figure 3)

Appendix C

Tables showing the total number of patent applications and the country of origin for the different welding techniques

Priority country	No. of priority applications
US	145
DE	46
FR	40
JP	40
AT	29
CN	23
EP	14
GB	8
KR	5
AU	4
BE	4
CH	2
IT	2
RU	2
SE	2
TW	2
CA	1
LU	1
MX	1
NL	1
PL	1

Table C1: The total number of patent applications and the country of origin for the cold metal transfer welding method (Figure 6)

Priority country	No. of priority applications
US	753
JP	629
DE	465
CN	302
GB	269
FR	127
KR	87
RU	58
EP	46
BE	32
CH	29
SE	20
IT	16
TW	14
AT	13
NL	11
RO	9
AU	8
CA	8
FI	5
PL	5
NO	4
BR	3
CZ	3
SG	3
DK	2
ES	2
IN	2
GR	1
IL	1
MY	1
TR	1

Table C2: The total number of patent applications and the country of origin for the cold pressure welding method (Figure 6)

Priority country	No. of priority applications
JP	3331
US	1497
CN	1300
DE	1052
RU	381
GB	380
KR	276
FR	179
EP	116
TW	51
SE	42
AT	35
CH	31
AU	20
NL	19
RO	17
IT	16
NO	15
ZA	12
BR	11
BE	10
CA	9
FI	9
IN	8
PL	8
ES	7
CZ	5
DK	5
IL	5
PT	5
HU	4
MX	2
AR	1
IB	1
LU	1
MY	1
NZ	1
SG	1

Table C3: The total number of patent applications and the country of origin for the friction stir welding method (Figure 6)

Priority country	No. of priority applications
JP	3583
CN	1375
US	865
DE	740
RU	536
KR	421
FR	262
GB	116
BE	51
IT	51
AT	49
EP	40
TW	23
CH	22
SE	19
NL	11
PL	11
AU	10
CZ	9
ES	7
CA	6
UA	5
IN	4
LU	4
BR	3
IB	3
IL	3
FI	2
HU	2
DK	1
GR	1
HK	1
IE	1
MY	1
NO	1
RO	1
TR	1

Table C4: The total number of patent applications and the country of origin for the resistance spot welding method (Figure 6)

Proirity country	No. of priority applications
JP	602
US	475
DE	331
FR	105
CN	70
GB	54
EP	41
BE	19
KR	15
CH	14
IT	13
AT	12
AU	9
CA	6
NL	6
RU	5
ES	5
SE	5
NO	2
TW	2
BR	1
CZ	1
FI	1
GR	1
HU	1
IL	1
LU	1
NZ	1
SG	1

Table C5: The total number of patent applications and the country of origin for the steel/aluminium welding method (Figure 6)

Front page photo: iStock.com/PJ66431470

Norwegian Industrial Property Office
Street address:
Sandakerveien 64,
0484 Oslo
Norway

Postal address:
Postboks 4863, Nydalen
0422 Oslo
Norway

Customer Service Centre: +47 22 38 73 00
E-mail: post@patentstyret.no

nipo.no

Partner
nordic patent institute