Global Competitiveness of European Surface Technology
east whitepaper

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Global competitiveness of European surface technology

Summary

The aim of the present whitepaper is to recommend future directions for the European surface technology industry to remain relevant and competitive, and furthermore, to suggest supportive actions stimulating this development. This is done from a pan-European view based on an analysis of the present status of the competitiveness of the European surface finishing industry and the challenges it is facing. The work has been carried out by a group of European experts representing different sectors and regions.

For decades, globalisation has made offshoring of production a common activity by moving mass production to low-wage countries in Asia, but also relocation of production within Europe from the West to the East has been significant. In addition to cost reduction, vicinity to growing markets has been an important argument for relocating production. Success of offshoring has shown to depend on many more parameters and some backshoring is experienced, especially of high-tech products with the main drivers being: increasing costs at offshored facility, lack of quality, limitation in lead time and flexibility, limited access to skills and knowledge, risk of losing know-how and IP, and brand equity. Increasing production automation counteracts offshoring and Europe holds in general a strong position and a strong trend in automation.

Surface finishing is not a stand-alone industry, but an integrated part of manufacturing of most products and thereby an integrated part of the manufacturing chain and follows the rest of the manufacturing if offshored. The European surface finishing sector has an estimated annual turnover of US$ 114 Bn and employs around 900 000 people, and has had an annual growth rate of 3.6% during the last decade. We will soon learn how this is affected by the ongoing pandemic. The sector accounts for about 5% of all manufacturing of products. About 1/3 of the surface finishing is estimated to be done by sub-contractors and 2/3 in-house. The average size of European subcontractors is stable at between 11 and 12 employees with the majority having less than 10 employees, which is a challenge for the future development.

Since surface finishing is an integrated part of manufacturing, it is not recommended to create a European strategy for bringing back offshored surface finishing. Already offshored production might soon be obsolete due to technological changes. Instead it is recommended that the European surface finishing sector prioritises advanced production technology for new high-tech and high added value products, and take advantage of disruptive changes in society and technology shifts where completely new areas of application of surface technology can arise, e.g. within sustainable energy systems.

To be successful, surface finishers should meet expectations to the following selling points: Price, quality, short lead time, innovation ability, meeting legislation, and brand equity. This is challenging, especially for the many small firms, and should be obtained by increased automation, close cooperation between all functions and partners in the value chain, and secured and improved competence supply for all functions involved.

Basically, the solution can be described as improved education and improved organization between applied research, product development, production development and manufacturing. Each year tens of thousands of new employees are entering the surface finishing sector to cover many different functions (operators, engineers, experts, salesmen, managers, etc), but the present education and training programmes do not offer the needed capacity. Instead many new employees have to rely on in-house training, which is extra critical for small firms that need to meet new demands on technology implementation, legislation, etc. There is a strong need for
pan-European actions to coordinate and expand education and training offered by schools, universities and professional associations across Europe.

Overall competence and better theoretical understanding leads to better reliability, quality, and cost-efficiency. It becomes easier to communicate between the different actors in the value chain stimulating efficient technology transfer from academia to supply house and practitioner in industry and increase innovation support to speed up the innovation rate.

Students must be attracted to choose an education and career related to surface technology even though the field is less visible, since it is not a branch of industry with its own separate products. Coordinated actions are needed to market surface technology/finishing as an interesting field with direct impact on daily life and essential for the future development of society.

Europe has a strong tradition in surface finishing and the sector is characterized by a significant diversity (specialisation). The right competence supply and organisation can make ‘cooperative diversity’ a European stronghold.

Within its stated role the EAST intention is to act to facilitate the recommended development supporting the surface finishing sector.
1. Introduction

The European Academy of Surface Technology (EAST) held in connection with the recent celebration of its 30 years anniversary several workshops with the purpose of giving expert views on the future development of surface technology in Europe (Leisner and Baumgärtner 2020). The theme of one of the workshops was European competitiveness in a globalised world. Following the workshop, development of this theme has continued and is now published in the format of the present whitepaper.

The purpose of the whitepaper is to recommend future directions for the European surface technology industry in order to remain relevant and competitive, and, furthermore, to suggest supportive actions stimulating this development. This is done from a pan-European view based on an analysis of the present status of the competitiveness of the European surface finishing industry and the challenges it is facing.

Since relocation of production is the direct consequence of changes in competitiveness, it is relevant to clarify the nomenclature used in connection to changes in location and ownership of production as presented in Figure 1. Production relocated to another European state is termed ‘nearshoring’, whereas relocation of production, that once had been outshored, back to Europe is termed ‘backshoring’. Third party surface finishers, e.g. job shop coaters, are becoming ‘insourced’ if they join a strategic partnership with e.g. customers or other parties in the value chain.

![Figure 1: Nomenclature for spatial relocation and ownership of production seen from a European perspective (modified from Foerstl et al. 2016).](image)

In the following discussion it appears relevant to distinguish between the group of 15 countries (EUold15) that were member states of the European Union in 1995 and the group of 12 new countries (EUnew12) that became member states during 2004-2007. Alternatively, with the addition of Croatia that became a member in 2013 (EUnew13). Furthermore, since Eurostat data are not complete for all member states, it has been necessary to modify the division into groups called ‘West Europe’ and ‘East Europe’ (see Table 1).
<table>
<thead>
<tr>
<th>Designation</th>
<th>Included EU member states</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUold15</td>
<td>Members from 1 January 1995: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK</td>
</tr>
<tr>
<td>EUnew12</td>
<td>New members by 1 May 2004 and 1 January 2007: Bulgaria, Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia</td>
</tr>
<tr>
<td>EUnew13</td>
<td>New member by 1 July 2013: ‘EUnew12’ + Croatia</td>
</tr>
<tr>
<td>West Europe</td>
<td>‘EUold15’ without Luxembourg*</td>
</tr>
<tr>
<td>East Europe</td>
<td>‘EUnew13’ without Czechia, Estonia, Malta*</td>
</tr>
</tbody>
</table>

*) Eurostat data are not complete for these countries

Table 1: Designation of groups of EU member states compared in the present report.
2. European manufacturing industry

For decades, globalisation has made offshoring of production a common activity by moving mass production of e.g. electronics to low-wage countries in Asia, but also relocation of production within Europe from the West to the East has been significant. In addition to cost reduction, vicinity to growing markets has been an important argument for relocating production. However, European small and medium size enterprises (SMEs) prefer nearshoring to culturally close countries in Europe over offshoring to countries in Asia (Kinkel and Maloca 2007).

It has been shown that outsourcing represents a trade-off between lowering costs and improving innovation capability, and that manufacturing and supplier integration in the product design processes is beneficial when products and manufacturing processes are complex (Bengtsson et al. 2009). This supports the general expectation that it is mainly simple mass production that has been offshored. However, after decades of offshoring, this picture is changing. The main reasons for offshoring are challenged by rapidly increasing competence in advanced production technology and innovation capability in target regions for offshoring. For example, China and India have thousands of graduate scientists and engineers many of which are educated in the West, implying more ready adoption of new technology, as well as improved communication. On the other hand, costs are increasing in traditional low-wage countries. In China, the growth is around 7% p.a., which is far more than in Europe, leading to erosion of the cost advantage. Expert salaries could grow even more. This is gradually reducing the economic enticement to offshore production.

![Figure 2: Share of companies in the German metal and electrical industry that have experienced offshoring and backshoring, respectively, in the previous two years. The arrows indicate the percentage of backshoring of the percentage of offshoring done in the previous period ending two or three years before. Thus the 2% backshoring experienced in the period up to 2012 is one sixth (17%) of the 12% offshoring seen in the previous period (S. Kinkel and C. Zanker 2013).](image-url)
During the last decade, an increasing trend to backshore production to Europe has been observed. Backshoring of production is most frequent in high-tech industrial sectors like electrical equipment, communication equipment, and transport equipment (Dachs and Zankel 2014). It is worth noting that these are sectors highly relevant for the surface finishing industry.

A recent survey (Stentoft et al. 2016) analysing 20 reports, gives the main drivers for backshoring as (in decreasing order of importance),

1) Increasing costs at offshored facility  
2) Lack of production quality  
3) Limitation in lead time and flexibility  
4) Limited access to skills and knowledge  
5) Risk of losing know-how and IP  
6) Brand equity

Grappi et al. (Grappi et al. 2018) found that ‘brand equity’ could benefit from both the statement ‘made in home country’ and ethical issues related to social responsibility (e.g. labour conditions). It is likely that even ‘made in the EU’ and arguments related to low environmental and climatic impact would be relevant, too.

Ancarani et al. (Ancarani et al. 2015) analysed 249 European and US backshoring cases and found that the probability of backshoring is higher within technology-based industry, for SMEs, for companies with headquarters in Europe, and when offshoring in the first place has been done to Asia. The main drivers were found to be declining cost differentials, cultural differences (leading to issues in interpretation of priorities etc.), and quality issues.

<table>
<thead>
<tr>
<th>Target for offshoring</th>
<th>2010-2012</th>
</tr>
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<tbody>
<tr>
<td>EUnew12</td>
<td>55%</td>
</tr>
<tr>
<td>China</td>
<td>30%</td>
</tr>
<tr>
<td>Asia (rest of)</td>
<td>25%</td>
</tr>
<tr>
<td>EUold15</td>
<td>11%</td>
</tr>
<tr>
<td>North America</td>
<td>8%</td>
</tr>
<tr>
<td>Other East Europe</td>
<td>2%</td>
</tr>
<tr>
<td>Latin America</td>
<td>2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source for backshoring</th>
<th>2010-2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUnew12</td>
<td>49%</td>
</tr>
<tr>
<td>Asia (rest of)</td>
<td>27%</td>
</tr>
<tr>
<td>EUold15</td>
<td>17%</td>
</tr>
<tr>
<td>China</td>
<td>14%</td>
</tr>
<tr>
<td>North America</td>
<td>4%</td>
</tr>
<tr>
<td>Other East Europe</td>
<td>0%</td>
</tr>
<tr>
<td>Latin America</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 2: Preferred regions for German companies performing offshoring or backshoring during 2010-2012. The sums exceed 100% because some companies offshore to or backshore from more than one region (S. Kinkel and C. Zanker 2013).
A specific study focuses on relocation trends in the German manufacturing industry after the global economic crisis 2008-2009 (Kinkel and Zanker 2013). It concludes that cost-based advantages of outsourcing to low-wage countries decline. Offshoring of production from Germany has decreased after peaking in the late 1990s followed by a local peak around the EU enlargement to the East in 2004. It is stated that about one sixth of offshored production is backshored within a period of a few years. Figure 2 illustrates this development for the metal and electrical industry, which is important for the surface finishing sector. Thus, in Figure 2, the 2% backshoring experienced in the period up to 2012 is one sixth (17%) of the 12% offshoring seen in the previous period. The main reasons for offshoring are labour cost (but with weakening trend), and proximity to markets and other relocated production capacity. The target regions for offshoring of production is in order of importance: EUnew12, China, Asia outside China, and EUold15 (see Table 2). The main reasons for backshoring are lack of flexibility and quality. Loss of know-how is not a dominant, but a rising reason for backshoring. The source regions for backshoring are in order of importance: EUnew12, Asia outside China, EUold15 and China. Relocation of production to and from Asia outside China has a significant increasing trend, whereas relocation of production to and from Eastern European countries outside the EU is very limited.

A study on Italian manufacturing industry (Calia and Pacei 2017) found a significant negative effect of outsourcing (either within the home country or to a foreign country) on productivity, at least in the short-run, and a non-significant effect on profitability.

Furthermore, transportation is still very cheap, but it is likely that transportation soon will be taxed much harder to reflect the real load of transport on the environment, e.g. CO₂ tax. This will favour nearshoring over offshoring; at least for products manufactured for the European market.

![Figure 3: Density of installed industrial robots (number of robots per 10,000 employees) in 2011 and 2017 (based on data extracted from International Federation of Robotics, IFR).](image-url)
Increasing automation, and more recently also digitalisation of manufacturing, makes offshoring to low-wage countries less profitable. Kinkel et al. (Kinkel et al. 2015) concluded that European companies using industrial robots are less prone to offshore production outside Europe since labour cost becomes a less important factor.

Figure 3 shows the development in density of installed industrial robots (number of robots per 10,000 employees) after the financial crisis. The 15 European countries with highest robot density are compared with the most important counterparts internationally. South Korea is in a clear leading position and with a strong increasing trend. In Europe, Germany is leading followed by Sweden and Denmark. China has the highest growth rate of 360% compared to the world average of 55% for the period 2011-2017, indicating that China is moving toward higher value production. It is noticeable that Japan which is usually considered as a robotic pioneer country is declining from being at the same leading position as South Korea. Slovakia, Czech Republic, and Slovenia are the European countries with the highest growth rates well over 100% for the period. In contrast, the UK has a remarkably low density of industrial robots and with a slow development compared to other industrialised countries. In fact, the UK is now below the world average density of industrial robots. This links to its current reduced share of manufacturing in GDP of 10%.

Overall, Europe holds a strong position in automation of manufacturing (IFR 2018). The metal industry, of relevance for the surface finishing sector, is expanding the use of industrial robots as part of Industry 4.0 automation strategies. This development is slower for SMEs but is expected to increase as industrial robots are becoming smaller, cheaper, and more user friendly.

The dedicated manufacturing system (DMS) based on the assembly line principle has been operating since the early 20th century with high throughput capacity, but low flexibility. It is made for mass production of the same product over long time. In contrast, the introduction of automation in the 1960s represented by CNC machines and automated material handling is a flexible manufacturing system (FMS) designed to produce multiple products in small batches of high variety. The drawback is that the high flexibility demands high investment costs. Today’s challenge in production planning is that the life cycle of modern products is much shorter than the life of the machines producing them and thereby also shorter than the depreciation time. In addition, there are increasing demands on number of variants, customisation within product families, or changes due to adaptation to new legal requirements. The result is increasing number of market segments and regional requirements. On the other hand, it provides an opportunity for differentiation from competitors. This development has enhanced the need for reconfigurable manufacturing systems (RMS) prepared to meet future need for rapid changes in product and volume of production. RMS are characterised by being divided into independent but interlocking units with compatible interfaces where additional investments in capacity and function are made when needed, e.g. when new technologies become available. To be agile, close cooperation between product development and production development including equipment suppliers is needed. Complete reconfigurable production lines are still uncommon, but elements like reconfigurable fixtures, tooling and material handling solutions are widespread. Overall, modern manufacturing often needs a mix of dedicated, flexible, and reconfigurable solutions (Koren and Shpitalni 2010).

The internal market of the European Union and the strong integration in and adaptation to the EU system by nearby countries are important for risk reduction when the global situation has shown to be less predictable. Recent global events that illustrate potential risk factors by offshoring are global political conflicts resulting in trade wars and high- or low-intensity military conflicts, and the most recent pandemic outbreak.
3. European surface finishing industry

Even though Europe has a long history of scientific excellence and industrial innovation in surface technology, the surface finishing industry is not a stand-alone industry. It exists in the form of sub-contractors (job shops) and in-house surface finishing as an integrated part of manufacturing of most products and thereby an integrated part of the manufacturing chain, and follows the rest of the manufacturing if offshore. The decision to offshore is based on an analysis of the overall manufacturing chain and follows the motives discussed in the previous Section, rather than a separate analysis of the surface treatment manufacturing step, since separation of interdependent key processes by partial outsourcing leads to problems of additional costs and managing dependencies (Bengtsson and Dabhilkar 2008). However, nearshoring of surface finishing over borders in Europe is common in border areas, where a low cost or higher technology-using finisher is in easy reach of the manufacturer.

By being an integrated part of product manufacturing, the European surface finishing industry is under pressure from low-wage countries in Asia. Those countries are not just offering cheap and simple coatings like galvanising of nut and bolts. Their scientific competence is now comparable to Europe, and additionally the chemical suppliers are acting worldwide, so everyone has access to the same base of processes.

Size

Since the surface finishing industry is not a stand-alone industry, and because it operates not only in dedicated sub-contract finishing firms, but also in a “hidden” way in captive in-house finishing departments of manufacturers, it is difficult to find reliable data on the size of the industry and how it performs in the market. A few recent reports have tried to compensate for the lack of information, which will be referred to in the following.

According to Eurostat code SIC 2561 data for 2017, the size of the European sub-contractor sector within ‘treatment and coating of metals’ is: 283,000 employees, 25,400 firms and a turnover of € 31 Bn (Larson 2019). Figure 4 shows the trend in turnover for the sub-contractor sector over the past two decades. During 1999-2008, the average growth rate was 7.0%, but 22% of turnover was lost through the recession following the financial crisis in 2008. Since then, the average growth rate has only returned to half of what it was before the crisis. We will soon learn what effect the ongoing pandemic crisis will have on the turnover in 2020 and beyond. The most recent data from Eurostat show that GDP for the EU dropped 14,4% in the second quarter of 2020 compared with one year before (Eurostat 2020), indicating that the effect could be on the same scale as under the financial crisis.

Figure 4: Turnover of European sub-contractors of treatment and coating of metals (based on Eurostat data).
The Eurostat data exclude both coating of non-metals e.g. plating on plastics, and in-house surface treatment. Concerning the size of the industrial in-house surface treatment sector it has been suggested that it is at least comparable with the turnover of job-shop finishing and may be considerably more. It is difficult to access reliable data on the in-house sector, with many large in-house surface finishing departments operating outside of the normal supply chains. Anecdotal evidence from the UK Metal Finishing Association – now the Surface Engineering Association (SEA) - (Bennett 1992) indicated that across the three main process applications then, electroplating and related processes, heat-treatment, and industrial paint/powder coatings, overall practitioner turnover split might be about 1/3 sub-contract to 2/3 in-house (Larson 2017). It is therefore reasonable to expect that surface finishing employs more than half a million in Europe with a turnover of at least €60 Bn. This is in line with ZVO (ZVO 2020) which estimates that European surface finishing employs around 440 000 people (at the same time acknowledging that it was missing firms registered differently in the statistics) and has a turnover above €0.1 M per employee. However, the in-house sector, and thus the total surface finishing sector, may be considerably higher.

Figure 5: Share of metal finishing sub-contracting of total manufacturing turnover for 15 European states in 2017 based on data from Eurostat and UN (Larson 2019).

As noted above, surface finishing is an integral part of manufacturing in general. How much it is integrated can be seen from by plotting official national sector sub-contractor turnovers for Eurostat sector SIC 2561 (Treatment and coating of metals), against manufacturing turnover data for these countries (UN data). Figure 5 shows a strongly correlated linear relationship, indicating that sub-contract surface finishing turnover comes to about 1.5% of associated manufacturing for European countries. The same has been shown to be valid for Japan and USA, too (Larson 2012:3).

It is likely that total surface finishing would follow the same trend but at a significantly higher valuation, at least 4% and probably more of associated manufacturing. For example, in the UK the engineering coating industry was in 2010 estimated to be just above 4% of the total industrial manufacturing (Matthews 2011). Although not a huge contribution in financial terms it cannot be emphasised enough that surface finishing enhances a very large proportion of manufacturing and thereby in added value. That Italy is placed above the trend line in Figure 5, and Germany below, might indicate that Italy has a higher share of sub-contractors than the European average and vice versa for Germany.
In Figure 6, a similar comparison has been made between Eurostat sector SIC 2561 (Treatment and coating of metals) and Eurostat sector SIC C25 (Manufacture of fabricated metal products). It is seen that sub-contract finishing counts for more than 7% of turnover in the fabricated metal products sector.

To try to overcome the uncertainty of surface finishing market value, Larson (Larson 2020) has recently attempted to estimate the size/value of the total of surface finishing industry globally, and in the European Union, from publicly quoted values of sales of paint and powder coating materials to coating firms and in-house departments. The market sales value of this particular group of finishing process materials is better documented and probably more reliable than others e.g. electroplating. Official statistics for sales of these materials to user industry companies for the EU (Eurostat code C20.301), Japan (Bureau of Statistics code 1644), and the USA (Bureau of Census code 325510) together with coatings trade organisations data, and estimates of paint and coatings global market values from 11 consultancy reports have been accessed. In addition, the estimated value of the Chinese market in paint and coatings sales has been estimated from six consultancy reports giving data for the APAC region, for which the estimated China contribution (~60%) is known. Using referenced multipliers, the amounts that these data have increased throughout the supply chain to total surface finishing activity globally has been estimated. The resulting averaged calculations of the total surface finishing of all types carried out by sub-contract and in-house operations for EU and globally are thought to be about US$ 114 Bn and approaching US$ 800 Bn, respectively, for 2017; for the end of 2019 the likely market values will be higher. The standard deviation for averaging these many and varied data sources is less than 10%, showing a reasonable degree of confidence in the final estimates, within the assumptions made.

Figure 7 shows the calculated share of total surface finishing, in manufacturing in these regions, in a number of EU countries, Japan and USA from statistics office data on paint/powder sales, and China estimated from consultant reported paint/powder sales, converted to practitioner paint shop turnover and further converting to total surface finishing (Larson 2020), and a similar relationship is seen to that given by sub-contract finishing (Figure 5) but with a higher share of manufacturing value, as expected; about 6% globally and 5% for EU. This indicates that total surface finishing in the EU is about three times that in the sub-contract sector. Change of any of the multipliers used e.g. the percentage of paint/powder material sold for industrial coating, will obviously influence these estimates. According to these estimates around 900 000 people are employed with industrial surface treatment in Europe.
Figure 7. Overall sub-contract plus in-house surface finishing activity turnover calculated from paint/powder sales turnover for 12 European countries plus EU (from Eurostat SIC code C20.301), Japan (from Bureau of Statistics code 1644), USA (from Bureau of Census code 325510), and China (from APAC paint/powder sales) vs. their manufacturing turnover from UN SIC-D (2017). (Larson 2020).

<table>
<thead>
<tr>
<th>Year</th>
<th>West Europe</th>
<th>East Europe</th>
<th>Ratio West/East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterprises number</td>
<td>16329</td>
<td>15060</td>
<td>15293</td>
</tr>
<tr>
<td>Turnover €M</td>
<td>20670</td>
<td>24644</td>
<td>27101</td>
</tr>
<tr>
<td>Employees 1000x</td>
<td>205</td>
<td>203</td>
<td>183</td>
</tr>
<tr>
<td>Employees/enterprise number</td>
<td>12.5</td>
<td>13.5</td>
<td>12.0</td>
</tr>
<tr>
<td>Turnover/employee €k</td>
<td>101</td>
<td>121</td>
<td>148</td>
</tr>
<tr>
<td>Average personnel costs €k</td>
<td>31.6</td>
<td>36.1</td>
<td>45.9</td>
</tr>
<tr>
<td>Share of personnel costs in production, %</td>
<td>31.7</td>
<td>30.1</td>
<td>27.8</td>
</tr>
</tbody>
</table>

Table 3: Comparison of the metal finishing sub-contracting sectors in West and East Europe (data from Eurostat)

**Competitiveness indicators**

One of the key measures may be size of firm in the sector. New technologies and legislative compliance in addition to continuing production are likely to require firms to take on new skills and knowledge, which would imply some sort of critical mass needing to be reached. It has been shown that the share of R&D employment among metal finishing sub-contracting firms is low and becomes lower with decreasing firm size (Larson 2012:2). For many years sectors have been
urged to increase average firm size to take advantage of economy of scale but over the last two decades this does not appear to have happened.

Eurostat data for the sector SIC 2561 have shown no obvious increase in mean size with the average number of persons employed per firm across the European Union remaining quite stable at between 11 and 12, but with a marked difference in average size between Western and Eastern Europe sectors at about 12 and 7, respectively (Table 3). In addition, according to these data the largest grouping of firm size in countries, and therefore throughout the EU, is the 1-10 employees/firm group, with few firms being large, e.g. the UK average is 17 employees, but 60% have less than 10 (Larson 2019). There is also marked deviation in average firm size between countries (Figure 8). The relatively larger ones are Germany 24, Austria 21, UK 17, and in East Europe, Romania being exceptional at 22; Poland, despite being a large sector with overall subcontractor SIC 2561 turnover now greater than that of the UK, having a very small average firm size of 7.7.

Some national sector trade associations quote larger average sizes from their membership, but it is believed that this apparent discrepancy is a result of associations having a disproportionately larger fraction of bigger firms from the national sector.

The migration of manufacturing over the past two decades from developed West European sectors to lower cost East European sectors is a result of cost factors in the latter sectors giving productivity and competitiveness advantages to manufacturers. Table 3 shows how some of these factors have developed since 2009, and show clearly that while the cost advantages enjoyed by manufacturing in the Eastern Europe sector a decade earlier were beginning to erode through steady convergence of these productivity factors in East and West (Larson 2012:1), it appears that this convergence has slowed in more recent years, meaning that, at least in cost, some advantages in nearshoring will still be evident for the foreseeable future.

**Figure 8:** Average number of employees at surface finishing sub-contractors 2017 calculated from Eurostat data.

In a recent study of the Nordic surface finishing industry (Leisner and Nielsen 2019), it was revealed that mass-production of printed circuit boards, reel-to-reel plating of electronic parts and galvanising of simple components have in principle vanished. Most of the surviving firms are relatively advanced, even though many are small. A large fraction of the firms experiences backshoring mainly due to quality issues, but also due to lack of confidentiality, logistics problems, and demand on environmental friendliness. Key factors for the future are access to skilled employees and high degree of flexibility. Surprisingly, automation is not highlighted as a key factor, maybe because most of the firms are small. Firm size is a concern and it is suggested that there is a lower critical limit in size of number of employees to be able to meet demand on
qualified skills in diverse areas such as integration in customers’ product development, logistics, process and quality control, legislation compliance, etc. Modern production is complex and demands a proportion of skilled and educated employees. People in production are becoming better educated, but it is a slow trend. Whether this critical size limit is 10 employees, as suggested, or higher, is not clear at present but it should be noted that at the low sizes quoted above a lot of companies, and indeed regional sectors, would struggle to take the next technological step up. The whole East Europe sector averages only about 7 employees/firm.

Although little research has been done in the surface finishing sector on the relationship between firm size and technological development, Figure 9 shows the difference between UK and German sub-contract zinc and nickel electroplaters in the amount of production processing which is estimated by the firms to be automated. The differences are noteworthy and should be seen in the context of the average size of German platers being significantly greater (about 50%) than UK platers. It may also be that the German emphasis on technology (‘Technik’) and known differences in national culture play a part in early adaptation of new technology (Larson 2000; 2001). Figure 10 using data from the same study indicates that the electroplating sub-contract sector in each country shows clearly the trend of greater company size leading to more automation, but with the extent of this being greater in Germany than in the UK, even in the same size range, showing cultural differences playing their part. Even though this comparison is two decades old the recent development in application of industrial robots (Figure 3) confirms that this large difference in automation between Germany and the UK remains and might even have grown.

Overall, surface treatment production systems have the qualities to be or become a reconfigurable production system. Components contributing to reconfigurability in plating could e.g. be adjustable anode configuration, and pulse plating supported by computer modelling, and simulation of the process. In addition, broadly the same equipment and production line can often be used if an alternative process is installed e.g. replacement of hexavalent Cr for legislation compliance reasons by trivalent Cr or another electrolytic process.

![Figure 9: Difference in % processing automated between UK and German zinc and nickel sub-contractor electroplaters in 1999 (Larson 2000; 2001).](image-url)
Figure 10: Comparison of the degree of electroplating process automation in the UK and Germany as a function of firm size. Specific size ranges of estimates of automation fractions: 1 = 0-25%; 2 = 26-50%; 3 = 51-75%; 4 = 76-100% (Larson 2000; 2001).

The diversity in market share of different process types within Europe is significant. Figure 11 presents the distribution between process types (electrolytic, hot dip, heat treatment, paint, and plastic/powder) for five major European states carried out by sub-contractors. A more comprehensive analysis has previously been published by Larson (2012:2), who concluded that these differences in market share remain steady over time.

Figure 11: Market share for sub-contractors of process types for some European states in 2017 based on Eurostat Prodcom data (Larson 2019).
### 4. Challenges of the European surface finishing industry

During several decades production has moved to low-wage regions. The threat is that production continues to move away. In addition, European companies working in the field of surface technology are facing fundamental changes. Many applications especially in the traditional strong industries such as automotive, mechanical, and electrical engineering decrease in volume or become obsolete due to technological changes. With less manufacturing in Europe, knowledge is lost and with this the innovation capability among practitioners and researchers will decrease over time. Knowledge loss, and transfer to others, lead to compromise of security of strategic industries like energy, military, and IT among others. To counteract this development three main actions can be emphasised:

1) Backshore production to Europe
2) Anticipate and avoid situations where existing European production is offshored
3) Develop new production in Europe

Even though, we are experiencing a backshoring trend, it is small compared to the amount of production that is offshored. It is probably not worth investing resources in an European strategy for backshoring surface finishing that is already established abroad and probably integrated with other production steps, and maybe even in proximity to the main market. Due to the ever-faster technology development, offshored production might often be considered as old and less attractive to bring back. In this sense, it is much more efficient to prioritise that production already established in Europe, stays in Europe. Finally, to have a long-term strong surface finishing sector in Europe, it is important to develop new production by being agile in adaptation of new technology and meeting new market demands. New products and new types of production driven by disruptive changes in society like Industry 4.0, AI, transition of the energy system (Paatsch 2016, Nielsen et al. 2018, Mølmen et al. 2019), circular economy, regulations toward minimal environmental footprint and minimal consumption of strategic raw materials/conflict minerals, and 100% traceability are all opportunities for Europe.

Table 4 lists the most important selling points and their connected challenges for the European surface finishing industry. In the best case the industry should be able to turn one or more of these selling points into unique selling points to differentiate from competitors. The selling points are discussed in the following.

<table>
<thead>
<tr>
<th>Selling point</th>
<th>Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>Be cost-effective in global competition.</td>
</tr>
<tr>
<td>Quality</td>
<td>Do right first time.</td>
</tr>
<tr>
<td></td>
<td>Maintain high yield in production.</td>
</tr>
<tr>
<td>Lead time</td>
<td>Efficiency in communication, implementation of production of new products, and correction of problems.</td>
</tr>
<tr>
<td>Innovation ability</td>
<td>The development is faster than ever. If the innovation rate is too slow, product development and production is overtaken by others.</td>
</tr>
<tr>
<td></td>
<td>Lack of enough technically and scientifically knowledgeable staff at practitioner sites.</td>
</tr>
<tr>
<td>Meeting legislation</td>
<td>Production outside Europe is not complying with European regulations.</td>
</tr>
<tr>
<td>Brand equity</td>
<td>Production in Europe.</td>
</tr>
<tr>
<td></td>
<td>Ethical and environmental responsibility.</td>
</tr>
</tbody>
</table>

Table 4: Important selling points and their connected challenges for the European surface finishing industry.
Price

Discussion of production cost is often simplified to focusing on salaries but must be also connected to efficiency and thereby it is better to look at the ratio between turnover and personnel costs. As discussed in Section 2, when the economy is growing in target regions for offshoring the benefit from offshoring is declining. In addition, one also needs to consider the risks associated with paying a lower price for offshored production related to quality, sustainability, logistics, confidentiality, political decisions, and unpredictable natural disasters. In most cases it is worth paying extra for risk reduction in production of quality products.

The ongoing automation and digitalisation of the manufacturing industry summarised under the term Industry 4.0 makes personnel costs a less important factor. Industry 4.0 is an opportunity to develop production in Europe from an already strong position in automation. Concerning surface finishing the challenge is that modern automation should meet the need for cost-efficiency and flexibility in smaller production volumes and specialisation represented by RMS as discussed in Section 2. Furthermore, it should be accessible for the many SMEs among the surface finishers in Europe.

Quality and lead time

Quality and lead time are closely connected since customers expect deliveries to be both right and fast. Figure 12 illustrates the cumulative loss/profit during the innovation process starting from research followed by product development. Thereafter, production development is needed to be able to launch the product on the market. During these steps, investments are growing progressively. Launching the product on the market indicates the initiation of the commercialisation step. To begin with, production costs will still exceed income from sales. If the product becomes a success, sales will exceed production costs and start reducing the cumulative loss. Finally, when the cumulative loss has been turned into a cumulative profit, the product becomes a business success. The curve representing the cumulative loss in the figure is also known as the ‘death valley’ of product commercialisation. Any unexpected cost or time delay will make the valley bigger and jeopardise the product becoming a business success. It is likely that a delayed product launch might result in shorter time on the market for the product. Therefore it is important to have continuous control over the quality of the innovation process from the very beginning. This demands close cooperation between the different functions involved during the process (R&D, product development, production development, production, customer relations, sub-contractors, etc). The subject of continuous risk reduction in the innovation process on the way to commercialisation in relation to surface technology is discussed further by Leisner and Johansson (Leisner and Johansson 2019). An additional challenge related to making innovation based on research results is that it is not easy to get risk funding for research on high TRL (technology readiness level), and product and production development. This results in prolongation of the time until product launch. A general trend in manufacturing is that product generations are becoming shorter with reduction in quantity of specific parts. Instead more variation in product families is developed, resulting in more frequent reconfiguration of the production facilities. Everything else being equal, it is more difficult to maintain quality and agility in a cross-border supply chain. Companies want to have less interfaces between the different parts of the production chain.
Europe has a strong tradition in surface finishing, and it is essential to keep the knowledge base in Europe to have a strong innovation ability. At present, there is a pronounced lack of enough technically and scientifically knowledgeable staff at practitioner sites. With the estimated 900 000 persons employed within the field of surface finishing in Europe, the number of new employees entering the field annually covering all types of functions is counted in tens of thousands. No matter if the employees are operators, experts, managers, etc., they need proper education for their function in the field to perform efficiently with quality in cooperation with colleagues holding complementary functions. The education in the field, is on a national basis and very dispersed. Only a few dedicated technician and engineering programmes exist. Otherwise, surface finishing related teaching is limited to individual courses and lectures in engineering programmes. Complementary to this, several of the national professional associations throughout Europe, e.g. the IMF in the UK, offer additional training for professionals. Nevertheless, the sum of people taught in the diverse programmes and courses in Europe is far from the tens of thousands needed. Instead, most new employees in the field have to complement their existing skills with internal training in the company. An additional issue is that many of these are employed in small SMEs or similar sized finishing departments of larger manufacturing companies where the opportunity for getting internal training is limited. This accentuates the question on what is the critical mass and competence of companies to meet challenges with respect to automation, new technology implementation, quality, compliance with more and more demanding legislation? Can some of these requirements be deemed non-competitive at company level, and thus, open up the possibility of shared expertise? It is in any case, essential to have close cooperation between product development, design, and manufacturing when products and manufacturing processes are complex. This makes the demand for competence supply and multidisciplinary cooperation and trust between partners in the value chain more important than ever. There is a strong need for pan-European actions to coordinate and expand education and training offered by schools, universities, and professional associations across Europe.
**Legislation**

Surface finishing plants in Europe must comply with many European, national, and local regulations. The basic purpose of the regulations is to improve the protection of human health and the environment, and harmonise the European market. It is becoming an increasingly complex process for surface finishers to understand and meet the demands of regulations, especially for SMEs that often cannot afford a specialised function for the purpose.

The European Chemicals Agency (ECHA) under the European Union is promoting a strategy for substitution of hazardous substances in European production. Unfortunately, the strategy does not suggest actions prohibiting import of products produced using the same hazardous substance in third countries. This will result in unfair competition for European surface finishers that have to give up established process chemicals like chromate and cyanide and instead turn to more expensive processing and challenges concerning process stability. At the same time, the health and environmental problems are not solved, just relocated to third countries which most likely have less control than in Europe. Therefore, European regulations for production should be valid for all products sold in Europe, independent of where they have been produced. Otherwise regulations lose their legitimacy. In a situation with equal regulatory demands on production, experience in meeting REACh could conform as a possible niche advantage for European surface finishers.

**Brand equity**

It is becoming increasingly important for companies to show that in addition to attaining good financial results they are taking societal responsibility e.g. by publishing annual sustainability reports relating to the UN Sustainable Development Goals. The driving force in this matter could be within the company or coming from different groups of stakeholders, since it is risky for well-established brands to be connected to poor working conditions and environmental scandals as well, even when the responsibility formally is on a sub-contractor.
5. The future development of European surface technology

European strength is cooperative diversity. Europe has a common ground in culture and legislation, but still with a tradition of diversity that stimulates creativity and mutual inspiration. The diversity in processing throughout Europe as seen in Figure 11 can create added value by benefiting from specialist competence originating from regional unicity e.g. the Swiss watch industry (Figure 13).

Figure 13: Example of electroformed micromechanical components from the Swiss watch industry. UV-LIGA microelectroforming of calendar wheel in two levels (Courtesy of Mimotec SA).

For European companies it is more valuable to prioritise new high-tech and high added value products (high quality) and advanced (automated, digitalised, RMS) production technology than fighting to get “old” high volume production back by backshoring. This will demand increased focus on specialisation, e.g. in nanotechnology, environmentally friendly technology, products with high degree of customisation, e.g. implants and just in time production of essential spare parts. The industry should be ready to take advantage of disruptive changes in society and technology shifts where completely new areas of application of surface technology can arise, e.g. 3D-printed components needing specially adapted surface treatment (Figure 14). This is particularly the case in the area of new and alternative energy systems. New coating processes can be used, for example, for the deposition of catalytic materials and protective layers for fuel cells or to produce three-dimensional electrode structures for applications in new battery systems by use of electroforming processes.

Another advantage of companies in the field of surface technologies is that they have special competence in the application of chemical processes and they are able to create completely new business in the field of the generation and storage of alternative energy such as hydrogen electrolysis or energy storage by means of redox-flow cells. These are just a few examples of the fact that, even during technological changes, new opportunities for a successful alignment of the company strategy can arise.

Furthermore, Mulone et al. (Mulone et al. 2020) propose a sustainable approach in development of electroplating processes (Figure 15) with the strategy to avoid critical raw materials (EU 2017).
and substances of very high concern (ECHA 2020). Finally, the metals should be recyclable when used as coatings. Circular economic solutions could be a USP demanding competence and probably “support” by tough EU legislation.

![Figure 14: Example of a fully automated finishing module for surface treatment of 3D-printed metal parts (Hansal 2019).](image)

Education on all levels related to surface technology complemented by continued training programmes for professionals should be better coordinated to meet the needs in content and volume of the industry.

![Figure 15: Three steps toward a sustainable approach for electrodeposition (Mulone 2020). Figure used with permission of copyright holder.](image)
Overall competence and better theoretical understanding leads to better reliability, quality, and cost-efficiency. It becomes easier to communicate between the different actors in the value chain stimulating efficient technology transfer from academia to supply house and practitioner in industry and increase innovation support to speed up the innovation rate. An unexpected side effect of the ongoing pandemic could be that it becomes much easier to realise on-line education of high quality that can be given on demand and be accessible from anywhere in Europe. This type of joint European training will also generate cross-border connections and strengthen the European dimension of the surface finishing sector.

Nevertheless, offering educational programmes and industrial training does not automatically solve the problem. Students must be attracted to choose an education and career related to surface technology even though the field is less visible, since it is not a branch of industry with its own separate products like e.g. automotive. Coordinated actions are needed to market surface technology/finishing as an interesting field with direct impact on daily life and essential for the future development of the society. Its importance in impacting and adding value to the great majority of manufactured components and products needs to be emphasised again and again, with strong examples of the properties conveyed to substrates by surface finishing e.g. corrosion resistant, high conductivity coating on electronic components in aerospace stopping aircraft falling out of the sky, etc. In addition, surface finishing is soon to become, if not here already, a trillion-dollar industry globally; not the biggest, perhaps, but with a major influence everywhere.

To accomplish the suggested development of the European surface finishing sector there is a strong need for ensuring that the firms have critical size and access to the needed critical competence. Small firms need to grow bigger and smarter, and be able to invest in new technology, or it should be attained through acquisition/merging/alliances that result in critical mass and access to strategic competence. It should be noted here that many such sub-contract surface finishing firms are owner managed, and issues of control are likely to be important. Perhaps this can be resolved in developing closer supply chain management relationships/partnerships, as with the older established Japanese style keiretsu partnerships in which the larger technologically stronger firm (often the customer) takes on a responsibility to aid its suppliers in e.g. adoption of new technology of mutual benefit to both, shared information technology and databases (Ellram and Cooper 1993; Lee et al. 2018; Birasnav and Bienstock 2019).

A stronger common communication about surface technology as an enabling technology with proven high added value together with stronger cooperation/alliances in the value chain should pave the way for easier access to capital for investments in product development and new production technology.

From a pan-European point of view, relocation of production within Europe, most often from the West to the East, is a natural part of the European ideal of free movement of people, goods, and services. It could add stimulation to the development of low-wage regions in Europe, which in the long run should be beneficial for Europe in general. However, the existing structure of many very small sized sub-contractors with the need of competence development to cope with future demands and lacking in resources to invest in new production technology, could hinder the evolution toward a more balanced and competitive intra-European structure of surface finishing providers. Batchler et al. (Bachtler et al 2019) recommend spreading innovations throughout the European economy to avoid spatial gaps in competence, cost-efficiency, and capacity in entrepreneurship.
6. The role of EAST in the future development

The mission of EAST is to promote Europe-wide science, research, training, and education in the field of surface technology and related areas in order to contribute to the integration, understanding and friendship between European people and individuals. EAST consists of pan-European members elected on the basis of their expertise and cooperative performance. The members represent both academic and industrial/research institute experience, and states in and outside the EU. By years of cross-national pan-European cooperative actions EAST has gained expertise across the surface technology process and industry spectrum and understands the asymmetric use of the various surface technology processes across Europe and the interdependence of East and West Europe industry supply chains.

With this unique combination of competences and strengths EAST and its members can stimulate pan-European cooperation in education and technology transfer by:

- using existing European funding tools to establish cooperation between education providers on all levels (from technicians to academic level) to make relevant education available all over Europe by taking advantage of a broad set-up of methodologies like e-learning, exchange of teachers, internships and summer schools. Sharing educational tools will increase efficiency and strengthen European networking.

- promoting cross-border intra- and inter-sectorial exchange of employees (professional schools, universities, equipment and process suppliers, producers, and customers). The present EAST exchange grant programme is, for natural reasons, of modest scale, but its existence within a strong network gives visibility that should be used to encourage stakeholders to make use of the many tools offered on the European level to support exchange e.g. within the Marie Skłodowska Curie programme.

- establishing closer cooperation with industrial surface finishers associations on national and European level to enabling the speeding up of technology transfer in the chain of university → supply house → in-house and sub-contract practitioner, and to communicate the importance of surface technology to relevant stakeholders (students, companies, branch organisations, funding agencies etc.).

- using its academic contacts in business schools and its sector knowledge to initiate and encourage targeted surface technology sector business performance and competitiveness research programs, on the basis that the sector is a benchmark for all manufacturing industry, both in-house and sub-contract, by being a critical part of a big proportion of manufacturing. The surface finishing sector, although substantial and important to much of manufacturing, has been little studied to date (e.g. Larson 2000, 2001, 2012, 2017, 2019, 2020; Dietrich 2016; Dietrich and Wald 2019; Zhu and Zolkiewski 2015), regarding its business performance, strengths and weaknesses and other business indicators. Such studies can lead to identification of weaknesses in effectiveness, and in turn lead to appropriate suggested improvement remedies.

- continuing to facilitate meetings between stakeholders and increase awareness in society of the importance of surface technology, e.g. by awarding the Schwäbisch Gmünd Prize for young scientists.
7. Conclusion

With the emphasis on competitiveness of European surface finishing in comparison with offshore to lower cost non-European regions and other developed regions, the ability of Europe to take on new finishing technology, and means of improving productivity e.g. automation, and the ability to understand and comply with new environmental protection and health and safety legislation it becomes increasingly important to understand the structure of the sector. With that, it is also important to be aware of the ways in which this may need to be amended to ensure development of improved competitiveness can take place.

First of all, the surface finishing sector is not a stand-alone industry, but integrated in overall manufacturing of products. Offshoring of production is a result of globalisation driven by cost reduction as well as vicinity to growing markets. Success of offshoring has been shown to depend on many more parameters and some backshoring is experienced, especially of high-tech products. Increasing production automation counteracts offshoring and Europe holds a strong position in automation. It is recommended that the European surface finishing sector prioritises advanced production technology for new high-tech and high added value products, and take advantage of disruptive changes in society and technology shifts where completely new areas of application of surface technology can arise.

It is estimated that the European surface finishing sector has an annual turnover of US$ 114 Bn and employs around 900 000 people. The sector accounts for about 5% of all manufacturing of products. Surface finishing adds value to almost any type of product. About 1/3 of the surface finishing is done by sub-contractors and 2/3 in-house. The average size of European sub-contractors is stable at between 11 and 12 employees with the majority having less than 10 employees.

To be successful, surface finishers should meet expectations to the following selling points: Price, quality, short lead time, innovation ability, meeting legislation, and brand equity. This is challenging, especially for the many small firms, and should be obtained by increased automation, close cooperation between all functions and partners in the value chain, and secured and improved competence supply for all functions involved.

Basically, the solution can be described as improved education and improved organization between applied research, product development, production development and manufacturing. Each year, tens of thousands of new employees are entering the surface finishing sector to cover many different functions, but the present education and training programmes do not offer the needed capacity. There is a strong need for pan-European actions to coordinate and expand education and training offered by schools, universities, and professional associations across Europe.

Students must be attracted to choose an education and career related to surface technology even though the field is less visible, since it is not a branch of industry with its own separate products. Coordinated actions are needed to market surface technology/finishing as an interesting field with direct impact on daily life and essential for the future development of society.

Europe has a strong tradition in surface finishing and the sector is characterized by a significant diversity (specialisation). The right competence supply and organisation can make ‘cooperative diversity’ a European stronghold.
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