Abstract: The present article makes the overview of the current situation in the Estonian metallurgical industry. It contains the assessment of the enterprise development during the recent years. The author mentions the general economic indicators of the enterprises of the sphere; in addition to that the questions of productivity are analyzed. Since the topic of the article is the influence of the productivity of the welding enterprise on the production process, the author also conducted the qualitative and quantitative studies in order to determine the current situation. In these studies, the greatest emphasis is directed towards the development of welding technology in order to provide the improvement of productivity. At the same time, there has been presented the assessment of the role of human resources in the present-day welding enterprise.

As a conclusion it may be stated that the product structure in the welding enterprises during the recent years has changed and become more complicated. However, this demands greater attention both to the improvement of productivity and provision of quality. In addition, the development of welding technology and personnel training is extremely significant.

Key words: welding enterprise; quality, productivity, implementation of new welding technologies

1. PRESENT SITUATION

Estonian companies in the field of engineering, shipbuilding, and metalworking have always held a high position and they have represented significant part of the entire processing industry. During last decade the form of ownership, production, markets, and also quality and staff requirements have undergone fundamental changes. Presently, the companies in the handling industrial sector are 100 % private capital based: Estonian, foreign or mixed capital, whereas generally dominates Estonian capital. During past ten years companies have undergone restructuring in connection with changes in the form of ownership and opening of new markets. Today most of considerable companies are medium-sized enterprises with 100 to 250 employees, or small enterprises with less than 100 employees. There are less than ten large (in Estonian terms) enterprises in handling sector with number of employees more than 500.

The development of the companies of Estonian engineering, shipbuilding and metalworking industry has contributed to the growth of capacity both in general production and export to European Union member states by 5 to 10 % each year. According to the data provided by the Estonian Statistical Office, the relative importance of handling sector has grown gradually approximately. 7–9 % in the
year. Export constituted almost 60% of the production. Export part in production increased by 7. The following illustrations show the position of handling industry sector in manufacturing and export.

In order to stay competitive on the international market, productivity needs to be improved. This problem is being more and more discussed in Estonia. The enterprises used in the research, i.e. metal industry, machine and apparatus manufacturing, shipbuilding and transport equipment manufacturing enterprises, are facing this problem. The following diagram shows the developments of enterprises in this industry sector.

![Graph showing enterprise development](image)

**Fig 1** Efficiency of enterprises

As can be seen, the efficiency of enterprises has increased by approximately 35-40% in the last 5-6 years (e.g. [3]). This is a good result, but many experts believe that in the next five years, the productivity and efficiency has to increase by at least 200% A prerequisite for such an increase is more complex products and more up-to-date technologies.

2. CONTENTS OF THE RESEARCH

2.1 Background

Increase in production and export capacities requires greater attention towards the quality of products and more urgent need for highly qualified staff. As welding and related technologies hold leading position in the companies of the above-mentioned industrial sector, more and more attention is paid to training and certification of welding staff; certification of welding procedures; quality control; certification of products and companies.

In the field of technology, significant changes have been observed during the last years. In general it has to be mentioned that products have become more varied and more complex. This, on its own accord, leads to implementing new technologies. During the last years, the welding volumes of thick carbon steels (thickness over 30 mm) have increased. At the same time, the welding volumes of stainless steels, including Duplex steels, has increased significantly (e.g. [4]). Additionally, there are several enterprises with important welding volumes of Al and Al alloys. All this means heightened attention towards welding technologies and heightened demands for the quality of welding. On the other hand, improving productivity is immensely important for staying competitive. Many enterprises have reached a conclusion that an optimum ratio between ensuring high quality of welding and increasing productivity, has to be reached (e.g. [5]). The key to solving this problem is developing the welding technology further and, if possible, mechanising, automating and robotising of welding.

2.2 Developing of technologies

Depending on the industry and also on the products, decisions have to be made about developing of technologies.

The processes accompanying welding are a big prerequisite for improving the productivity. In the following, such activities affecting productivity are shown that must get attention in a welding enterprise.
As shown on the scheme, the preparation processes have a significant role. Also, logistics and inventory management have an important role. Exact supplies of materials and smooth co-operation with suppliers enable savings of over 50% of the time spent on manufacturing of the products. Additionally, workplace order and routes within the enterprise ensure a significant saving in time spent (e.g. [4]). Also, the technical documentation and the relevant specifications must be correct and clearly legible. Both the preparations made by engineers and by welders and helpers have a deciding role. Also, vocational training must get special attention.

As cited above is not directly related to welding, so the implementing of suitable welding technologies and the availability of high-quality personnel ensure a balance of quality and productivity. Upon improving the productivity via rationalising the welding technologies, the following must be taken into account:

- Finding the suitable technological solution.
- Taking into account the individual properties of the materials to be welded.

![Fig. 3 135/121 welding process](image1)

Below an example is given about the technical peculiarities of material S355 joined by two different technologies.

![Fig. 4 135/121 welding process](image2)

Additionally, other technological parameters are shown in the following table.

<table>
<thead>
<tr>
<th>Welding method</th>
<th>Current A</th>
<th>Voltage V</th>
<th>Heat input KJ/mm</th>
<th>Welding speed cm/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 135</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 layer</td>
<td>140</td>
<td>18</td>
<td>0.4-0.5</td>
<td>28</td>
</tr>
<tr>
<td>2-5 layer</td>
<td>160</td>
<td>19</td>
<td>0.7-1.2</td>
<td>15</td>
</tr>
<tr>
<td>II135 /121</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 layer</td>
<td>220</td>
<td>28</td>
<td>2.4-2.6</td>
<td>12</td>
</tr>
<tr>
<td>2 layer</td>
<td>670</td>
<td>30</td>
<td>1.5-1.7</td>
<td>75</td>
</tr>
</tbody>
</table>

Table 1. Welding parameters/welding productivity
In the course of this research, the effect of modernising of welding technologies, to the productivity, has been analysed, taking into account the requirements for welding quality. In this article, a comparison of productivities of two different welding processes based on similar welding technologies is given. Welding method 135 and combined welding method 135/121 has been researched, tested and implemented in production. As can be seen, the time required for welding the test piece with each method differs over five times. In this case, only the time required for welding has been taken into account. This time is supplemented by preparations and other activities. In addition to this example, the possibilities for optimising the welding process 141, using equal welding parameters, have been researched. One option is to mechanise the process, i.e. auto use uninterrupted feeding of welding wire and helping holders for turning the welding detail. This would result in a time improvement of nearly 10 times upon manufacturing the detail. Additionally, an example could be given about using different shield gases for welding Al, analysed in the research related to his article, these shielding gases being mixtures of Ar and He. In this case, the higher heat input of He and the temperature of the electric arch allow for higher productivity. These are but some examples of developing the welding technologies. The most important role in improving the productivity of a welding enterprise lies in complex management of circumstances. As seen, there must exist a balance between productivity and quality. Of course, this is supplemented by costs related with mechanizing, automating and robotising of production.

The peculiarities resulting from the different properties of materials are a very important factor in optimising the technologies.

Fig. 5. Cracks in Al alloys/ welding

In this research, the most well known of these is the heat input resulting from welding and resulting in structural changes and stresses within the welded material. This results in various cracks and defects, also depending on the nature of the welded material. For example, one of the problems is macrostructure of AlMgSi T type welding seam, described below in this document. Upon welding Al alloys (group 23), it is extremely important to take into account the minimum heat input, the cleanliness of welding, and the temperatures between layers (e.g. \( T \)). Depending on material properties and the standard EN 1011-4, the max recommended temperature between layers is 100 °C. But in case of the welding seam researched, this was not observed and so microcracks appeared. Upon searching for ways to improve productivity, the various properties of different materials must be taken into account, otherwise there will be problems with quality and these will require a lot of costs and time to amend.

2.3 Training and certification of welding staff in Estonia

The preparation of welding co-ordinators and certification procedures for welders has been provided in Estonia for years. Our co-operation partners in that field include German and Finnish institutions.
According to the data of the Estonian Welding Association there are ca 2500 welders certified in compliance with EVS EN 287 today. Main training centres and certification units include the following: representative offices of Finnish welding schools, Lloyd, DVS, TÜV and training centres acknowledged on Estonian level.

Preparation of welding co-ordinators and certification of welders has been performed in compliance with the regulations of EWF / IIW , at the same time many short-term in-service courses have been conducted. Today the specialists of Estonian companies have had several opportunities to attend EWE (IWE), EWT (IWT), EWS (IWS), and EW1 (IW1) training. Training has been carried out in Russian, German and Finnish. At present moment there are ca 70 people prepared and certified in Estonia according to the abovementioned rules. Recently, Tallinn Technical University provided in-service training for welding supervisors. That particular training summed up EWF programmes, completing of which enables to orientate in modern welding standards, techniques and technology. At present more than 250 people have completed that training. Several studies concerning the issues of handling sector have been performed in recent years.

Fig. 6. Percentage of certified welders

When speaking of quality assurance, company’s need to have qualified workers, both as supervisors and welders is an important indicator to be mentioned. All companies undergoing the survey have established the office of welding co-ordinator. The percentage of certified welders of total number of welders (74.9%) serves also as another important indicator (e.g. [5]).

In the course this research, the fact was discovered that the problems of Estonian welding enterprises, related to training and attesting of the welding personnel, are very important. Often the lack of qualified welders and welding engineers is a big hindrance to expanding the production. This is caused by a rapid expansion of enterprises, moving of welders into abroad, and the current educational situation where significantly lower percentage of people leaving basic school are directed to vocational education than in other Member States of EU. Thus it can be concluded that the human factor is very important for improving the productivity.

2.4 Methods used in research.

For conducting the research, the data resulting from questionnaires was used – both the questionnaires of the authors of this document and the questionnaires of the Estonian Welding Association, giving information about welding personnel and demands for it. Additionally, data about implementing and using quality management systems in welding enterprises was gathered by these questionnaires. Also, other sources and scientific publications have been used in the research, and these are stated in the Annex of this article. The data about welding quality is gathered from professional literature and standards.

In addition to gathering data in various ways, also technological tests were conducted in the course of this research. These tests determined the optimum technological parameters for ensuring the productivity of welding processes. Tests for determining if a technology ensures the
required quality are very important in developing suitable technologies.

3. RESULTS AND CONCLUSIONS OF RESEARCH

This research was conducted within the framework of a scientific thesis and is based on previous thesis. Professional literature, relevant standards and other sources have been used upon publishing of this article.

The results of the survey show that Estonian companies where dominates welding technology, are active in different fields. Smaller companies consist of narrow specialists, but large companies manufacture very different products. Low alloy steels are generally used in welding. During the last 3 or 4 years the percentage of using fine-grain alloy steels and stainless steels (in addition to Al alloys) in welding has increased. Also, the thicknesses of the welded materials differ greatly.

The percentage of technologies used in Estonian industry and future trends speak for technologies that favour productivity and high quality of products. MIG/MAG welding percentage is also increasing as years pass by. The part of powder wires and blended gases grows even more quickly, which in turn refers to the intent of companies to increase productivity. TIG welding, which allows very high quality of welding, has also become widely used. Additionally, there are many examples of mechanising, automating and robotising of welding technologies.

Qualified personnel has very high importance in improving the productivity. It is important to solve the problems related to training of welders and welding engineers. In addition to this, the efficient working of quality systems of welding in the enterprise is important.

Quality assurance is also very important in improving the productivity. For this, it is unavoidable to conduct technological tests. Upon implementing new technologies, the WPS (welding procedure specification) approval is important. In case of more complex welding seams, work tests are also needed.

In future research, a higher attention will be given to issues of welding technologies for stainless and Al alloys. For proceeding with the research, conclusions have to be made about the possibilities of improving productivity, taking into account the necessary balance between improving productivity and ensuring quality.

4. REFERENCES