CHROMIUM AND MANGANESE IN WELDING – EXPOSURE AND THE NEED OF CONTROL MEASURES

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Abstract
Approximately 35 000 people in Sweden work as welders or gas cutters. In several other professions welding occur as a part of the work. The Swedish Work Environment Authority has recently decided to lower the exposure limits for hexavalent chromium and manganese. The new limits are valid from January 1st 2007. Due to the new Swedish occupational exposure limits it is important to investigate the level of exposure to chromium and manganese from welding fume and to gain more knowledge about the effect and use of existing control measures. Exposure measurements have been performed at six Swedish companies in order to examine the level of exposure to welding fume. Factors that influence the formation of welding fume have also been investigated. The use of existing control measures has been observed during welding and the results are discussed in relation to the new lower exposure limits set by the Swedish Work Environment Authority. Control measures that can reduce the exposure to welding fume are proposed.

Key words
Welding fume, formation, exposure limits, exposure, control, manganese, chromium.

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CHROMIUM AND MANGANESE IN WELDING – EXPOSURE AND THE NEED OF CONTROL MEASURES

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Introduction

Approximately 35 000 people in Sweden work as welders or gas cutters. In several other professions welding occur as a part of the work. It is well known that the welding fume formed during welding is a potential health risk to humans. For that reason hygienic exposure limits has been established for substances such as chromium and manganese that are present in welding fume.

The Swedish Work Environment Authority has recently decided to lower the exposure limits for hexavalent chromium and manganese. The new limits are valid from January 1st 2007. Due to the new limits it is important to investigate the level of exposure to chromium and manganese from welding fume and to gain more knowledge about the effect and use of existing control measures.

Exposure measurements have been performed at six Swedish companies in order to examine the level of exposure to welding fume. In addition a number of factors that influences the formation of welding fume have been investigated. The use of existing control measures has been observed during welding and the results are being discussed in relation to the new lower exposure limits set by the Swedish Work Environment Authority. Control measures that can reduce the exposure to welding fume are proposed.

Method

In the initial stage the Swedish Welding Commission provided contacts with twelve companies that had agreed to participate in the study. From the twelve companies six were selected by the following criteria:

1. Welding must be performed on stainless steel in order to be able to measure both chromium and manganese. Chromium is present in welding fume mainly when welding stainless steel while manganese occur in welding fume from welding both on stainless and unalloyed steel.
2. The welding must be performed with any of the welding methods MMA-welding, MIG/MAG-welding or FCAW. The reason for this was that all these methods are very common and especially MMA welding and FCAW produce a relatively high amount of welding fume.

The available control measures at the companies as well as if the welding was performed manually or automatically was also taken into consideration in the selection process.

The exposure measurements were performed through personal breathing zone sampling during one working day of approximately 8 h. At each company 2-3 samples of hexavalent chromium and 2-3 samples of respirable manganese were taken. Samples of total chromium and total manganese were also collected. At least one area sample was collected at each company. The sampling was made at the same time as the personal breathing zone sampling and during the whole working day. The welding method and steel used were considered when selecting welders for the breathing zone sampling. The area sampler was placed at a point to avoid draught and not in the nearest surroundings of a work station.

The samples of hexavalent chromium were analysed with UV/VIS spectrophotometry. The samples of respirable and total manganese and total chromium were analysed with ICP-MS. In addition, the filters used to collect respirable manganese were weighed to determine the amount of respirable dust on each filter. The filters used to collect total manganese and/or chromium was weighed in order to determine the amount of total dust on each filter.

During sampling the use of control measures as well as the effect and function of the control measures was observed in order to evaluate the measured levels of chromium and manganese. Information about welding method, steel and other welding parameters such as welding current and shielding gas were also collected. Information about the capacity of the ventilation was provided by the companies.

Results and discussion

Welding fume is formed when the welded steel and the consumable melts during the welding process. The fume consists of small particles of metal. Most of the particles are less than 1 µm, which means that they are respirable and reaches the alveoli tract when inhaled. Approximately 90 % of the particles in welding fume originate from the consumable. Manganese and chromium are alloy metals that are added to steel in various amounts in order to improve steel quality. The consumable normally has a composition similar to the composition of the welded metal. This means that the manganese content in consumables normally is 0,6-2 % and consumables for welding stainless steels contains between 12-23 % chromium.

Measurements of chromium and manganese

The personal breathing zone sampling of hexavalent chromium during welding on stainless steel showed that there is a considerable risk of exceeding the new exposure limit. The measured content of hexavalent chromium in the welders breathing zone is described in figure 1. Each dot represents one measurement and the letters A-F represents each of the companies participating in the study. The samples are grouped according to the welding method or the combination of welding methods used.

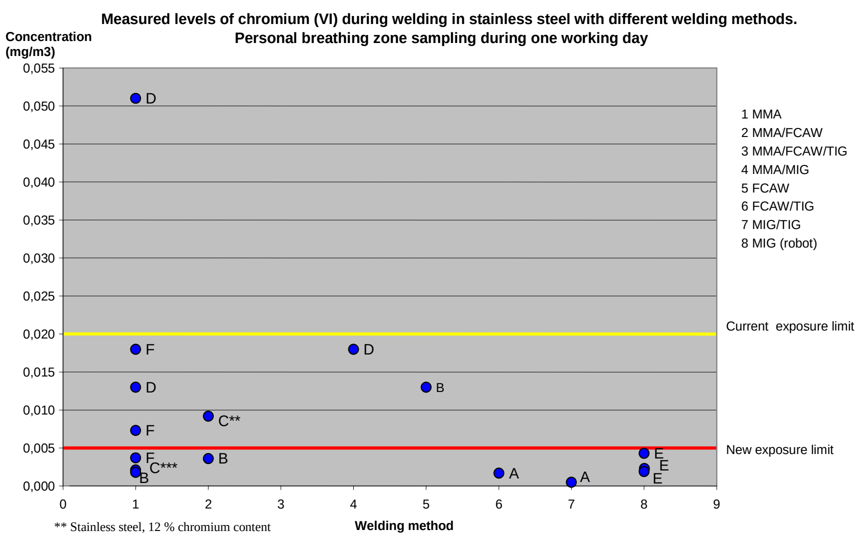

Figure 1. Levels of hexavalent chromium.

From the diagram it can be seen that for 7 out of 16 samples the content of hexavalent chromium exceeded the new exposure limit and one of those also exceeded the current exposure limit. During sampling of these 7 samples the local exhaust ventilation (LEV) were used partly during welding except in two cases: when the sample with the highest content of hexavalent chromium was collected no LEV was used and the sample collected during welding in a stainless steel containing 12 % chromium without using LEV resulted in a level of hexavalent chromium of 0,0092 mg/m^3. For the 9 remaining samples the content of hexavalent chromium were on average half of the new exposure limit.

Manganese was sampled both as total dust and as respirable dust. Respirable dust is thought to origin mainly from the welding process. Figure 2 shows the samples of manganese. One sample showed a content of manganese equal to the new exposure limit of 0,1 mg/m^3 and was measured under circumstances where no LEV was used. One sample had a content of 0,069 mg/m^3 and was collected under circumstances where the LEV was not used continuously. In all other samples the content of manganese was less than 10 % of the new exposure limit. The current exposure limit is 0,2 mg/m^3.

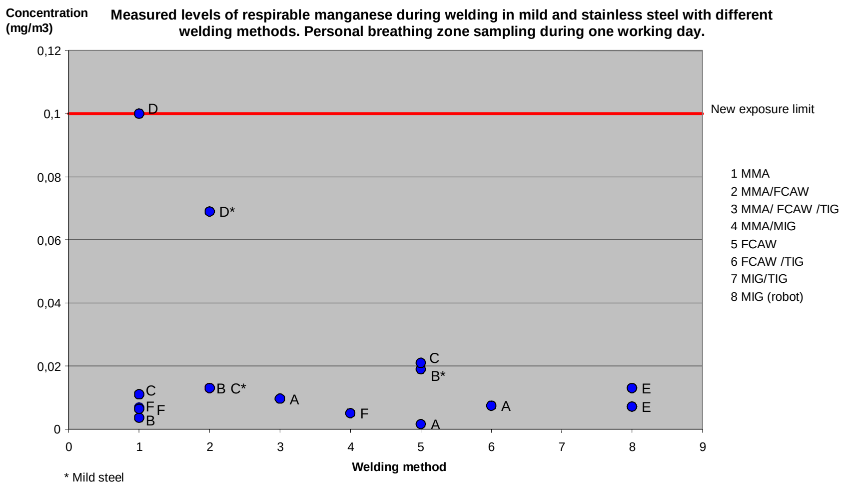

Figure 2. Levels of manganese measured as respirable dust.

The samples of manganese as total dust are compiled in figure 3. The sample of manganese as total dust with the highest content of manganese (0,12 mg/m^3) was collected when parts of the welding was performed in a confined space with difficulties to use LEV. The new exposure limit for manganese as total dust will be 0,2 mg/m^3, which is half of the current limit of 0,4 mg/m^3.

One sample of respirable dust exceeded the exposure limit of 5 mg/m^3 (5,4 mg/m^3) as can be seen in figure 4. The LEV was not continuously used during the sampling. When the sample with the second highest content of respirable dust was collected the welding was partly performed in a confined space.

The sampling of total dust resulted in levels between 0,27 mg/m^3 and 5,9 mg/m^3. The samples are compiled in figure 5. Grinding occurred frequently when the samples with the highest content of total dust were collected, which was also expected. All samples of chromium as total dust showed chromium contents less than 10 % of the exposure limit of 5 mg/m^3. The samples are compiled in figure 6.

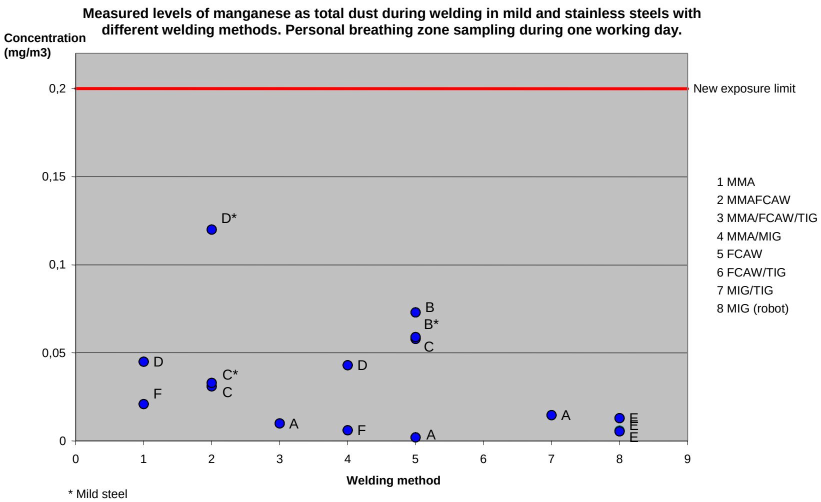

Figure 3. Levels of manganese measured as total dust

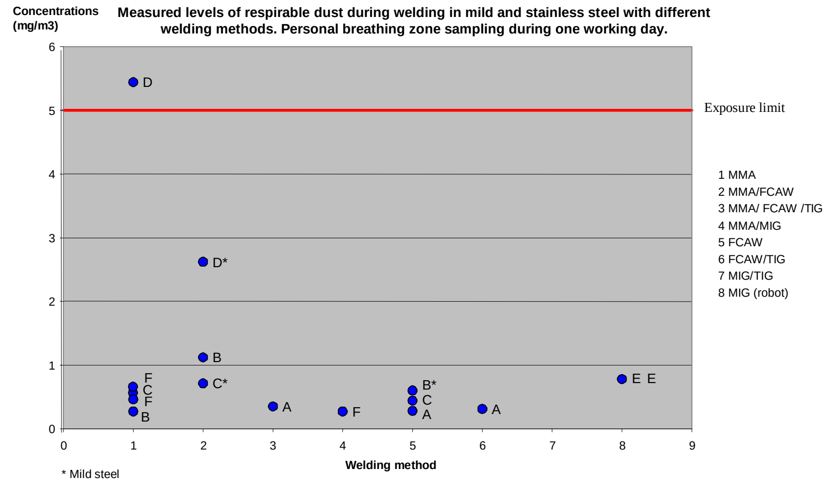

Figure 4. Levels of respirable dust.

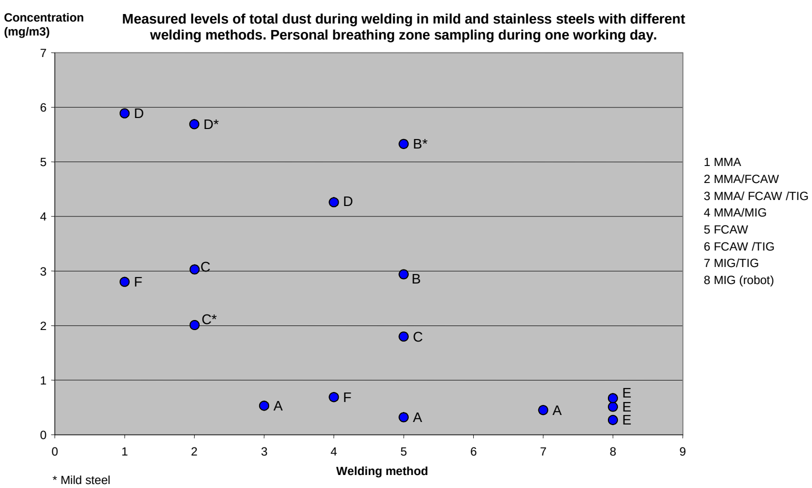

Figure 5. Levels of total dust.

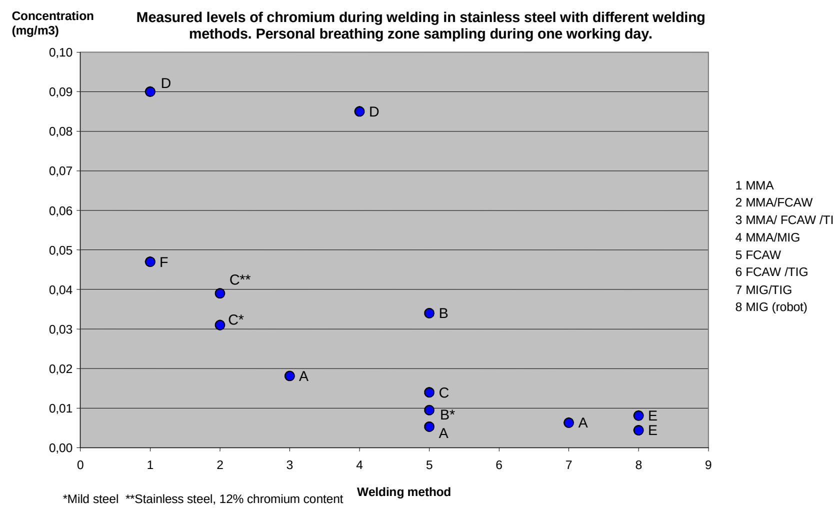

Figure 6. Levels of chromium measured as total dust.

Two area samples of hexavalent chromium were collected and both samples showed high background levels; 0,00087 mg/m^3 and 0,0021 mg/m^3 which is 17 % and 42 % respectively of the new exposure limit. These are considered to be high background levels and contribute to the levels of hexavalent chromium measured in the breathing zone. The background levels show that hexavalent chromium can spread in the workplace and that it can exist in the air in the hexavalent state.

The main factors affecting exposures to high or relatively high levels of hexavalent chromium, manganese and dust from welding and grinding is the use of LEV, the function and quality of the LEV, the general ventilation and possibly also the working position. Whether the welding is performed in a confined or open space also has a large impact on the exposure level, as could be expected. Factors with moderate impact on the exposure level are the choice of welding method and consumable. From the results of the sampling performed in this study no relations between welding method and the level of exposure could be seen. Factors with small impact on exposure level are the setting of current and voltage during welding and the choice of shielding gas.

Improvements of the working environment

An important measure to reduce exposure to welding fume is to capture the fume at the source and thereby minimize spreading. One way to achieve this is by using integrated fume extraction systems on welding guns. These are effective in extracting welding fume and as they are an integrated part of the welding gun they are always used during welding.

Local extraction systems placed on extraction arms or extraction fans are another ways to reduce spreading of welding fume. The handling of extraction arms as well as frequent use is crucial for the result. Most work requires the extraction arm to be moved around easily and the arms as well as the tubes connecting the extractor to the ventilation system should be in good condition. The flow in the exhaust system should be no less than 600-1000 m^3/h which is recommended by the Swedish Work Environment Authority.

A second measure is to reduce the amount of welding fume formed during welding. This can sometimes be achieved through optimization of the welding parameters although this can be hard to achieve due to the effect on the quality of the weld. It is known that the fume emission is dependent on the temperature in the weld pool; higher voltage or current results in a hotter weld pool and hence more evaporation of melted metal droplets. The formation of hexavalent chromium may be prevented by development of consumables with improved composition. Arc welding using a shielding gas containing traces of nitrogen monoxide may also reduce the amount of hexavalent chromium formed because the gas reduces the formation of ozone, which is a strong oxidizing agent that can oxidize trivalent chromium to hexavalent chromium.

The knowledge about the potential risk with welding fume and the importance of using LEV must be communicated. In a welding shop where welding as well as other kinds of work are performed simultaneously it is of great importance that the spreading of welding fume is controlled. As the fume spreads it will affect not only the welder but also other people working in the vicinity.

Conclusions
The critical substance was found to be hexavalent chromium, and the Swedish exposure limit valid from the 1st of January 2007 was exceeded in 44 % of the samples. The levels of manganese were found to be overall lower than the exposure limits, although the limits can be exceeded under certain conditions.

Observations showed that local extraction ventilation was not frequently used in many situations. This is thought to affect the working environment both as high levels of especially hexavalent chromium in the welders breathing zone as well as high background levels in welding shops.

The knowledge about the potential risks with welding fume should be increased. Minimization of formation of welding fume and minimization of spreading of welding fume are important measures in reducing exposure. This study indicates the importance of well placed and well functioning LEV systems.

Reference
Gavelin, Frida, Krom och mangan vid svetsning - exponering och behov av åtgärder, IVL rapport B 1675, 2006 (available at http://www.ivl.se/)