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# The influence of shielding gas and heat input on the mechanical properties of laser welds in ferritic stainless steel

M. Keskitalo[1,*], J. Sundqvist[2], K. Mäntyjärvi[1], J.Powell[2], A. F. H. Kaplan[2]

[1]University of Oulu, Oulu southern institute, Pajatie 5 85500 Nivala
[2]Dept. of Engineering Sciences and Mathematics, Lulea University of Technology. SE 97187

**Abstract**

Laser welding of ferritic steel in normal atmosphere gives rise to weld embrittlement and poor formability. This paper demonstrates that the addition of an argon gas shield to the welding process results in tough, formable welds. Post weld heat treatment and microscopic analysis has suggested that the poor ductility of welds produced without a gas shield is, to some extent, the result of the presence of oxides in the weld metal.


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*Keywords:* Laser welding; Ferritic stainless steel; Shielding gas

## 1. Introduction

Ferritic stainless steel is often used as a cheaper alternative to Austenitic stainless grades. The stress corrosion properties of ferritic stainless steels are actually better than those of austenitic stainless steels and they are therefore used for the manufacture of boilers, water heaters and automobile exhaust systems (Outokumpu Oyj, 2010, Kyröläinen and Lukkari, 1999). Ferritic stainless steel grades do not have the excellent weldability of their austenitic counterparts, which can be successfully laser welded without a shielding gas in order to achieve the good mechanical properties. The use of shielding gas improves the corrosion properties of the weld area generally.

* Corresponding author. Tel.: +358 40 775 0337
*E-mail address:* markku.keskitalo@oulu.fi


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When AISI grade EN 1.4512 (STS 409L) is welded using Gas Tungsten Arc (GTA), martensite is formed in the weld area due to nitrogen absorption from the different content of Ar + N2 back shielding gas when the N2 content is increased. When laser welding this material without the argon back shielding gas shield, the nitrogen content of the weld is increased further due to the increased temperatures in the weld zone compared to the GTA process (higher melt surface temperatures result in increased absorption). The use of Argon as the shield gas decreases the nitrogen content and therefore reduces the hardness of the laser weld (Lee et al., 2008 and Nakao et al., 2008).

According to Lakshaminarayanan laser welds of AISI 409M type ferritic stainless steels carried out with argon as a shielding gas had good ductility and formability at room temperature although the hardness of the weld was significantly higher than the base material as a result of rapid solidification (Lakshaminarayanan et al., 2012).

When welding with a CO2-laser the shielding gas is also used to remove the plasma plume which can absorb the laser beam at this wavelength, but in case of Yb:YAG laser beam the absorption by the plasma plume is minimal.

The aim of this present study was to investigate the ductility of ferritic stainless steel laser welds produced by using different welding energies and shielding gas arrangements.

## 2. Experimental Work

1.5 mm thick EN 1.4521 ferritic stainless steel was used in this study. This kind of stainless steel is alloyed with molybdenum, which makes it acid proof. Titanium and niobium are used as stabilizing elements in order to bind the interstitial elements Nitrogen and Carbon to stable Ti- and Nb- carbonitrides. Otherwise free interstitial elements in the matrix of the microstructure could create a brittle martensitic structure in welds. As a result of its higher Cr content, ferrite is more stable in EN 1.4521 than in EN 1.4512 (Balmforth et al., 1998). The Kaltenhauser ferrite factor (Kyröläinen and Lukkari 1999) for the EN1.4521 grade is 26.3 as compared to 12.3 for EN 1.4512. This indicates that the microstructure of a laser weld in EN 1.4512 material can contain martensite, but the microstructure of a weld in EN 1.4521 grade should be completely ferritic. The composition of the steel is given in table 1.

Table 1. Chemical composition of the EN 1.4521 type ferritic stainless steel grade

| C % | Si % | Mn % | P % | S % | Cr % | Ni % | Mo % | Ti % | Nb % | N % |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.019 | 0.49 | 0.52 | 0.026 | 0.002 | 18.0 | 0.2 | 2.01 | 0.12 | 0.40 | 0.026 |

The mechanical properties of the base material are shown in table 2.

Table 2: Mechanical properties of the EN 1.4521 ferritic stainless steel grade

| $R_{p0.2\%}$, MPa | $R_m$, MPa | A 5, % | A 50, % | Hardness, HB30 |
|---|---|---|---|---|
| 371 | 524 | 48 | 30 | 182 |

Laser welding of test samples was carried out using a Trumpf HLD 4002 diode pumped disk laser with a fiber diameter of 0.2 mm and focusing optics with a focal length of 300 mm. The collimation length of the optics was 200 mm and the beam parameter product was 8 mm*mrad.

This arrangement gave a focal point diameter of 0.3 mm. The root gas was blown into an enclosed space at the backside of the plate. The distance of the shielding gas nozzle from the surface of the plate was 1 mm. The shielding gas arrangements are shown in fig.1.

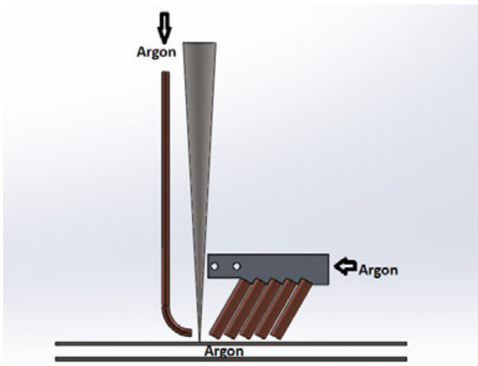


Fig. 1 The shielding gas arrangement.