metal JOINing

Influence of different welding processes on the mechanical properties of structural steel S960MC

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Introduction

The use of high strength low alloyed (HSLA) structural steels, such as S960MC, is constantly increasing in engineering industry today. Typical applications are structures in load handling, transportation vehicles and lifting equipment such as telescoping booms and cranes. The higher strength of the material offers increased payload and/or reduced weight of structures compared to standard structural steel [1, 2].
Welding of HSLA steel however, is more demanding since the process window of heat input and cooling rate is smaller. It has been proven that this steel can be welded succesfully with suitable welding methods, such as laser beam, laser-hybrid or modern gas metal arc welding. Also the filler metals play an important role in the welding of HSLA steels [3, 4].
The focus of this work is to study the influence of different welding methods and filler materials on the mechanical properties of S960MC welds.

Materials and Methods

8 mm thick sheets of structural steel S960MC were used for the welding experiments (Tab.3). Basic mechanical properties and chemical composition are given in Tables 1 and 2.

Table 1: Chemical Composition of S960MC in wt%

C	Si	Mn	P	Al	∑Cr, Ni, Mo	Cu	∑V, Nb, Ti	B	N
0.09	0.12	1.69	0.007	0.057	1.63	0.03	0.14	0.002	0.0057

Table 2: Mechanical properties of S960MC

Tensile Strength MPa	**Yield Strength** MPa	**Fracture Elongation** %	**Impact Toughness** J
1000-1150	≥960	10	≥47

Table 3: Weld Seam Geometry, Number of Passes, Heat Input and $t_{8/5}$ times for all examined welding processes

Welding Process	**Seam Geometry**	**Passes**	**Heat Input** kJ mm^{-1}	$t_{8/5}$ s
LHW	I	1	0.412	2.9
PW	I	1	1.427	12
TIG	U	5	0.419, 0.69	4, 7.5, 11
GMAW	V	3	0.605, 0.633	6.5, 9.5

Results

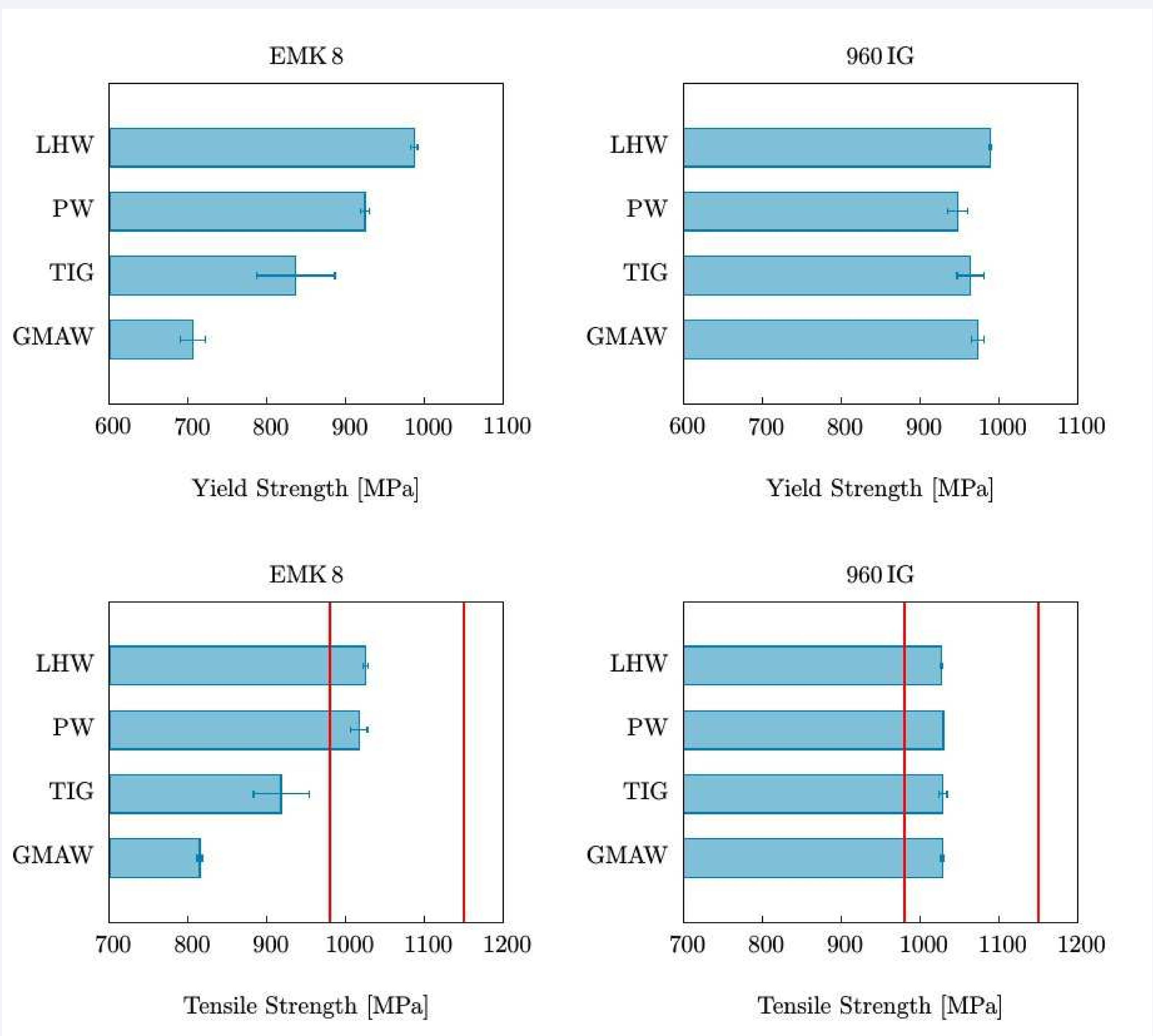

Figure 1: Yield and tensile strength of LH-, P-, TIG-, and GMA welds of S960MC steel using EMK 8 (left) and 960 IG (right) filler metal.

DIN EN ISO 10025-6 also requires an impact toughness of at least 30 J at −20 °C in the heat affected zone as well as in the weld metal. With the exception of the TIG welds using 960 IG all joints fulfill this specification (Fig. 1). The impact toughness in the weld metal of the EMK 8 welds increases with decreasing energy density of the welding process. This can also be correlated to the increasing strength of the joints. No trend regarding energy density of the process can be seen for the 960 IG joints.

The standard DIN EN 10025-6 [5] requires that welded joints of S960MC steel have a tensile strength in the range of 980 MPa to 1150 MPa. All joints, which were welded with the 960 IG filler metal, break in the base material and therefore fullfill the specification. Of all the welds that were welded with EMK 8 only the LH welds always break in the base material. Alltough two of the three plasma welds break in the weld metal, they still reach the necessary strength limit. The TIG and GMA welds show a significant drop in both yield- and tensile strength and cannot meet the requirements.

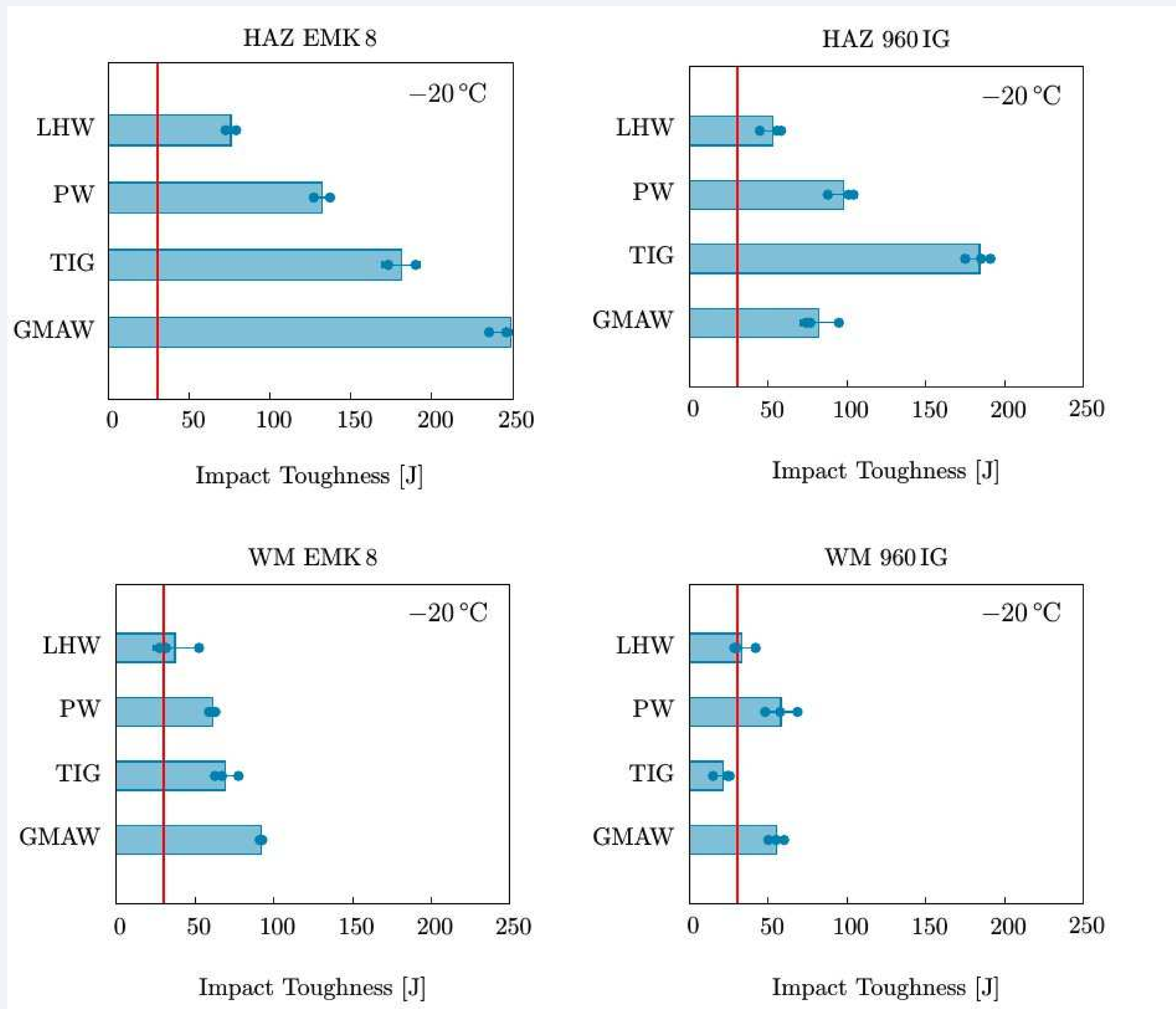

Figure 2: Impact toughness of LH-, P-, TIG-, and GMA welds of S960MC steel in the HAZ (top) and WM (bottom) for EMK 8 (left) and 960 IG (right).

Conclusion

- It could be shown that it is possible to weld 8 mm thick S960MC sheets using different filler metal and different welding techniques. 5 out of 8 tested combinations, LHW+EMK 8, LHW+960 IG, PW+EMK 8, PW+960 IG and GMAW+960 IG, fulfill the requirements stated by DIN EN ISO 10025-6.
- The use of undermatching filler material, i.e. EMK 8 is possible when welding with high power and power density welding techniques like laserhybrid- or plasma beam welding, which offers an economic benefit.
- For TIG and GMA welding undermatching with EMK 8 is not sufficient since the weld metal does not reach the neceassary strength level.
- The filler metal 960 IG produces sound welds for all tested welding techniques with the exception of the TIG joints. These fail the standard due to their lack of impact toughness in the weld metal.

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General foster notes / Acknowledgment
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