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L. Meyer. STRENGTH AND DUCTILITY OF WELDED JOINTS WITH AUSTENITIC AND MARAGING FILLER METALS UNDER DYNAMIC TENSILE LOADING. Journal de Physique Colloques, 1988, 49 (C3), pp.C3-35-C3-40. 10.1051/jphyscol:1988305 . jpa-00227721

HAL Id: jpa-00227721

<https://hal.science/jpa-00227721>

Submitted on 1 Jan 1988

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STRENGTH AND DUCTILITY OF WELDED JOINTS WITH AUSTENITIC AND MARAGING FILLER METALS UNDER DYNAMIC TENSILE LOADING

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RÉSUMÉ - Le comportement à la résistance et à la déformation de deux aciers faiblement alliés et à haute résistance typ 45CDV6-7, ainsi que des liaisons soudées en aciers austénitique et martensitique à durcissement structural, a été étudié en sollicitations dynamiques de traction avec trois vitesses d'essais jusqu'à $\dot{\epsilon} = 5 \cdot 10^2 \text{ s}^{-1}$. Tous les matériaux et liaisons soudées ont présenté une augmentation de la limite élastique et de la résistance à la traction, sans que l'on observe à vitesse plus élevée une diminution de la capacité à la déformation ou de la revirement de la mécanisme du rupture.

ABSTRACT - The strength and deformation behaviour of base metal and welded specimens have been investigated using impact tensile loading. These tests have been performed on two quenched and tempered low alloy steels of different hardness and on shielded arc weld joined with austenitic and maraging filler metals. With increasing strain rate the yield strength and UTS of all base metals and welded joints were enhanced, but no reduction of ductility resp. no change in fracture mode has been observed.

1. INTRODUCTION

The aim of this work was to establish the best method of welding for a construction where an intense dynamic loading has to be taken into account. The construction is expected to fail only after a reasonable amount of energy consumption and not with a more or less brittle fracture.

One problem to solve was to weld a high strength base metal with a relative high carbon equivalent of about 1 % without the occurrence of cracks in the heat affected zone or in the weldments. This was reached by shielded arc welding and by preheating of the plates up to 150°C.

The second question was, which kind of filler metals, an austenitic or a maraging type will yield to the best performance in strength and ductility under tensile loading at low, medium and high rates of strain.

2. INVESTIGATED MATERIALS AND TEST PROCEDURE

To establish an extended basis for a valuation the base metal was investigated for two levels of hardnesses (510 and 420 HV 30). The high hardness version was used for the welding, which was done with a maraging and an austenitic electrode. Because partially a heat treatment was used for annealing the joints, five materials have been investigated separately, tab. 1. Three levels of strain rates were used: quasistatic with $\dot{\epsilon} = 5 \cdot 10^{-4} \text{ s}^{-1}$, medium with $\dot{\epsilon} = 5 \cdot 10^{-1} \text{ s}^{-1}$ and high with $\dot{\epsilon} = 5 \cdot 10^2 \text{ s}^{-1}$ or more.

The gage length and the diameter for all tensile specimens was the same (length 18 mm; diameter 3,56 mm).

Tab. 1 : Welding parameter and materials

	Welding filler metal			Base metal	
	austenitic	maraging w.h.	maraging	510 HV 30	420 HV 30
Material No.	1	2	3	4	5
plate thickness	14 mm	12 mm	12 mm	12 mm	12 mm
Base metal	No. 4	No. 4	No. 4		
Welding parameter: filler metal name	Thermanit X	Novonit	Novonit	no welding	no welding
DIN-description	X15CrNiMn188	HFX750 X2NiCoMo1885	HFX750 X2NiCoMo1885		
electrode-diam.	1,2 mm	1,2 mm	1,2 mm		
protective gas	argon	argon	argon		
gas rate	18 ltr/min	15 ltr/min	15 ltr/min		
welding current	250 A	230-250 A	240-250 A		
welding voltage	28-29 V	25-27 V	25-26 V		
welding velocity	60 cm/min	60 cm/min	56 cm/min		
preheating	100-150°C	100-150°C	100-150°C		
cross-section of weld	V without gap	V with 1 mm gap	V with 1 mm gap		
heat treatment after welding	450°C 1h/air	450°C 1h/air	-	-	-

From the welded joints the small tensile specimen were cut out of the center of the plates containing a length of 8 - 10 mm of filler metal, Fig. 1. This is regarded as the necessary length for a nearly free deformation of the welded area, but with a rest of a support effect by the base metal, similar to the reality.

The strains are measured with 0,6 mm strain gages, attached to the weld resp. in the mid of the gage length. With a separate force measurement device, located directly behind the specimen, force resp. stress-strain-diagrams up to $\dot{\epsilon} = 5 \cdot 10^2 \text{ s}^{-1}$ are obtained. For higher strain rates a force measurement at the specimen itself is used, [1]. All materials are tested at room temperature.

Fig. 1 : Sampling crosswise to the welded joints

3. STRESS-STRAIN-BEHAVIOUR UNDER TENSILE LOADING

At quasistatic loading the base metal 45 Cr Mo V 67 exhibits a linear-elastic behaviour up to $\sigma = 1250$ MPa and after a stronger deformation strengthening a . 2 yield strength of $\sigma_y = 1500$ MPa. The following strengthening is low, fig. 2. At medium strain rates the yield stresses are increased slightly, but then a stronger strain rate sensitivity takes place, the Hookean solid is extended to about $\sigma = 1400$ MPa and the yield strength reaches nearly $\sigma_y = 1700$ MPa.

Fig. 2 : Stress-strain behaviour of base metal 45 Cr Mo V 67 with a hardness of 510 HV 30 at three rates of strain

The same dependence of the yield strength and UTS versus the strain rate - a velocity independent region up to $\dot{\epsilon}_p = 10^0 \text{ s}^{-1}$, followed by a rate sensitive region at higher loading rates - is presented by the base metal with the lower hardness of 420 HV 30, fig. 3. The yield strength and UTS is reduced adequately for about 250 MPa.

Fig. 3 : .2 yield strength σ_Y and UTS versus strain rate of base metal 45 Cr Mo V 67 in two grades of hardness

Compared with the base metals, the weldment with the austenitic filler metal, fig. 4, exhibits a reduced yield strength and UTS, but for welding, the static yield stress of nearly 500 MPa is acceptable.

Similar to an austenitic base metal [2] the strain rate sensitivity of σ_Y and UTS increases continuously with enhancing strain rate.

This tendency is the same for the welded joints with maraging filler metal, where the insensitive range of strain rate does not exist, fig. 5. But, the UTS of quasistatic loading reaches for the annealed and not annealed state with 1350 MPa the identical UTS level of the weak base metal.

Of course, the yield strength with $\sigma_Y = 1140 \text{ MPa}$ and 1210 MPa is slightly lower compared with $\sigma_Y = 1280 \text{ MPa}$ of the low hardness base metal. But the strain rate sensitivity $d\sigma/d\dot{\epsilon}$ of the welded joints is higher than of the weak base metal. This leads to the effect, that at strain rates between 10^2 and 10^3 s^{-1} the not annealed and annealed maraging weldment, No. 3 and 2, exceeds the strength of the weak base metal, resp. lies in between the strength of both base metals, fig.6, No. 4 and No. 5.

Fig. 4: .2 yield strength σ_y and UTS versus strain rate $\dot{\epsilon}_p$ of austenitic weld metal in annealed state

Fig. 5: .2 yield strength σ_y and UTS versus strain rate $\dot{\epsilon}_p$ of maraging weld metal in annealed and not annealed state

Fig. 6: Stress-strain-behaviour at $\dot{\epsilon}_p = 3 \cdot 10^2 \text{ s}^{-1}$ of the two base metals (No. 4 and 5) and the weldments (austenitic filler No.1; maraging filler without heat treatment No. 2 and maraging filler with heat treatment No. 3)

4. SUMMARY

This behaviour may be regarded as a respectable achievement, because -in addition- the ductility reaches the same amount as the base metals. Therefore a homogenous behaviour of a construction loaded dynamically will be guaranteed.

If a larger deformability combined with an extended homogenous strain is desired, then the austenitic filler should be chosen. The fracture strain exceeds more than 30 %, but the flow stress is reduced to about half of that of the maraging filler metal.

Under all conditions and materials, the fracture mode remains a ductile one. An embrittlement caused by the high strain rates doesn't occur.

5. REFERENCES

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