

Researches Regarding Heterogeneous Welding between Carbon and Stainless Steel used in Fabrication of Cylinders' Rod for Magnesium Alloy Extruders

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Abstract. Magnesium alloys are used more and more in automotive industry due to specific strength (ratio between tensile strength and density) of 158kNm/kg versus 46kNm/kg in case of structural steel. Another advantage of magnesium alloys is machinability, aspect and automated cast/extrusion. With this last procedure is possible to achieve high rate of productivity for complicate pieces, needed in automotive sector. Technologically, a big issue of magnesium alloy is its reactivity in contact with carbon steel, accentuated by high temperature and pressure from extrusion chambers.

1. Introduction

Welding austenitic stainless steels to carbon and low alloy steels are used in extrusion of magnesium alloys for automotive industry.[1,2]

In the process of extrusion, magnesium alloy is pushed by a piston rod inside cylinder. The most stressed element is the piston rod, charged with high compression loads, under relatively high temperature (400 Celsius) and high pressure (300...700MPa) as is shown in figure 1.

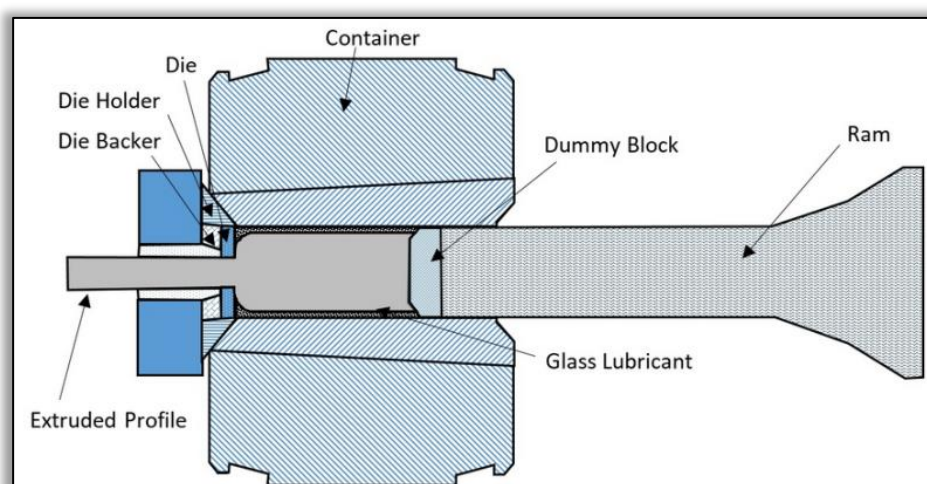


Figure 1. Typical process application. [1]

From this reason, piston rod (ram) is covered by a screwed bronze cap (dummy block). Very often rod's material does not resist and bend under stress (figure 2).



Figure 2. Bent rod. [2]

Study was pointed to realisation of dummy block – ram assemble using new materials and assemble to solve the next process issues [3–5]:

- Ram material was changed to high strenght medium alloyed steel.
- Dummy block amterial was changed to austenitic stainless steel
- Welding technology was developed to realize a strong and compact dummy block – ram assemble

Another problem during production process is the direct contact between high reactive magnesium alloy and dummy block. This lead in time to extensive wear and short life time.

For this reason, we implement a new design and technology, by welding a stainless steel dummy block. Welding of stainless steel dummy block can be done using specific welding procedures and filler materials carefully tested before.

Selection of filler material is key factor of the weld, with major impact over mechanical properties of assemble, stability at high temperature and corrosion resistance. From metallurgical point of view, welded joint is considered rather stainless than carbon steel, especially that over alloyed filers is used to obtain resistant microstructures when alloy with carbon steel.

2. Realization of prototype

2.1. Choosing of parent materials

From mechanical point of view, ram must have high mechanical properties at high temperature. Various steel grades were tried, and best results had 34CrNiMo6 (1.6582 EN 10027–2). From corrosion resistance and weldability, for dummy block the best results had austenitic stainless steel AISI304 (1.4301EN 10027–2).

2.2. Welding conditions

Although stainless steel does not require special condition, rod material has a high equivalent carbon (1.02%) and has high hardenability, susceptible to hydrogen cracking.

Welding joint to carbon steel must have slow cooling rate and reduce hardness in the heat-affected zone (HAZ), which creates a weld that is less brittle and more ductile. These characteristics are especially important for materials more susceptible to hardness at elevated temperatures, such as cast iron, medium- and high-carbon steel, or high- carbon-equivalency steel.

Another factor which requires preheating is dimension of welded parts (90mm diameter).

Taking into account these factors, result a preheating temperature of 360°C.

According with EN1011 standard, we have the next equivalent carbon for ram material [2]:

$$CE = (C + Mn)/6 + (Cr + Mo + V) + (Ni + Cu)/15 = 1.02\% \quad (1)$$

$$T_p = 679 \times CE - 160 \times \tanh\left(\frac{d}{35}\right) + 62 \times HD^{0.35} + (53 \times CE - 32) \times Q - 328 = 360^\circ\text{C} \quad (2)$$

where:

- CE is equivalent carbon 1.02%;
- d is assemble diameter 90mm;
- HD is hydrogen content of the weld metal 5ml/100g;
- Q is the heat input 2 kJ/mm.

Welding environment and filler material must be as dried as possible, at welding preheating temperature carbon steel has a much more hydrogen affinity and its related cracks versus austenitic steel.

2.3. Selection of filler material

Usually, stainless steel filler type ER308 can be used for this application. To improve weld quality, trials were made with ER309 filler which gives better results due to higher chromium and nickel.

From microstructure point of view, ER309 gives a higher ferrite concentration which is favourable.

From temperature point of view ER309 has higher nickel, so better results at working temperature of 400°C.

Figures 3 and 4 show the ferrite calculation for ER308 and ER309.

	Cr equiv.	Ni equiv.	PREN index	Ferrite content
Material 1	19.24	8.90	18.37	
Material 2	2.02	12.03	2.23	
Welding consumable	21.00	12.10	20.65	
Dilution 30 %	17.89	11.61		2.65

Welding consumable details				
Name	Material number	Type	DIN	ANSI
SE 308 L	1.4316	Stabelekt	E 19 9 LF	E 308 L-1
View product in Web shop				

Figure 3. Cr and Ni equivalent for ER308

	Cr equiv.	Ni equiv.	PREN index	Ferrite content
Material 1	19.24	8.90	18.37	
Material 2	2.02	12.03	2.23	
Welding consumable	24.70	13.90	23.66	
Dilution 30 %	20.48	12.87		8.49

Welding consumable details				
Name	Material number	Type	DIN	ANSI
SE 309 L	1.4332	Stabelekt	E 23 12 L	E 309 L-2
View product in Web shop				

Figure 4. Cr and Ni equivalent for ER309

For selected filler grade ER309 another check was made with Schaeffler diagram (figure 5).

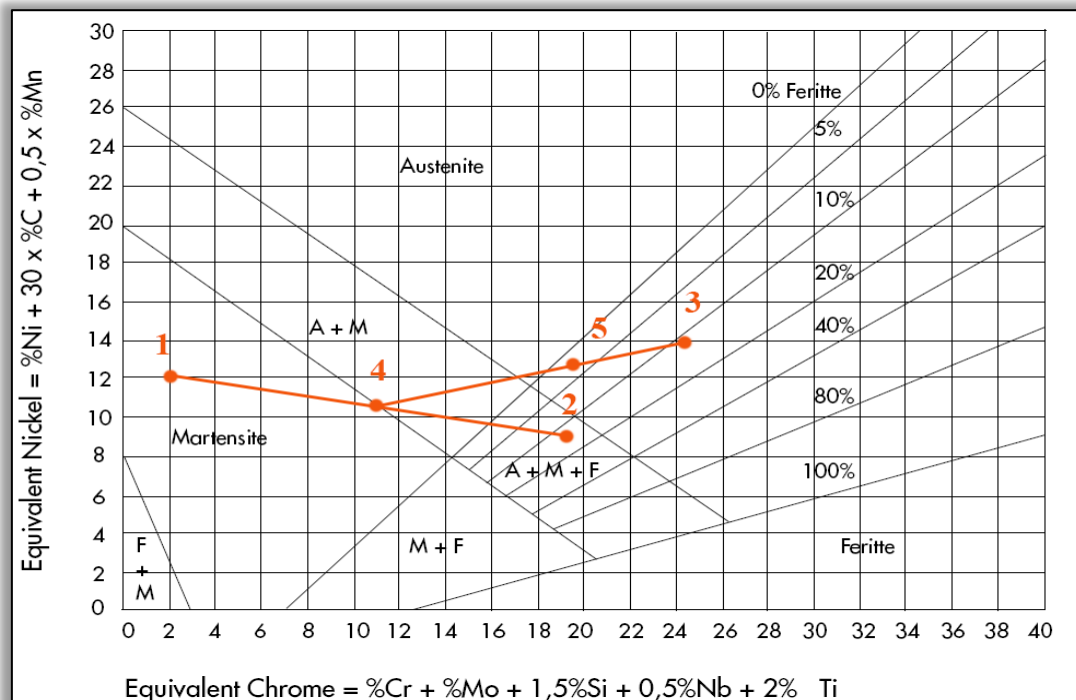


Figure 5. Schaeffler diagram: – point 1 represents rod material, carbon steel, grade; – point 2 represents cap material, stainless austenitic steel grade; – point 3 represents filler material grade ER309; – point 4 represents the mixture of rod and cap material; – point 5 represents the mixture of parents materials and filler material at a dilution (leverage) of 30% means 30% of parents material will participate in weld joint, rest being filler material.

3. Results of welding trial and conclusions

Trial was made using circular weld, using different filler materials, for filler materials half ER308 and for next half ER309. Welding procedure was MMA with 3.2mm electrodes at a current of 140 amps. Bevel angle was at 30 degree and height 10 mm.

For both filler materials weld joint was satisfactory and in transversal section no porosity or defect were observed (figure 6 and 7).



Figure 6. Joint preparation



Figure 7. Assemble welded

Chemical analyses of both welded joints shown difference in chemical composition, the most relevant is for carbon and chromium (table 1).

Table 1. Chemical compositions.

	Chemical composition, [%]											
	C	Mn	Si	S	P	Cr	Ni	Cu	Mo	Ti	V	Al
Dummy block	0.05	1.46	1.53	0.00	0.02	19.15	11.10	0.10	0.00	0.00	0.12	0.01
Ram	0.40	0.66	0.16	0.00	0.01	0.85	1.73	0.25	0.21	0.00	0.00	0.01
Filler ER309	0.12	1.75	0.45	0.03	0.03	24.00	13.00	0.37	0.37	0.00	0.00	0.00
Filler ER308	0.08	1.75	0.45	0.03	0.03	20.75	10.00	0.37	0.37	0.00	0.00	0.00
Weld with ER309	0.23	0.79	0.53	0.01	0.00	10.93	6.01	0.15	0.12	0.00	0.05	0.00
Weld with ER308	0.11	0.98	0.92	0.00	0.01	16.49	8.84	0.12	0.08	0.02	0.08	0.00

For ER309 filler, dilution of carbon is higher. Figure 8 shows assemble section.

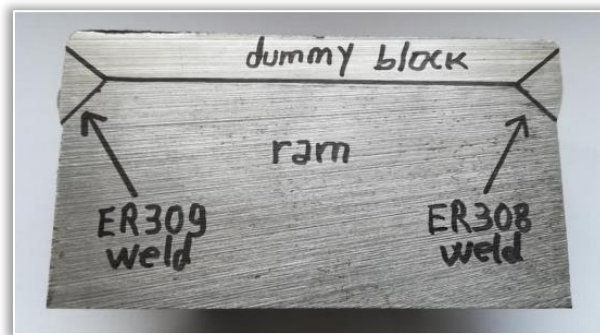


Figure 8. Assemble section

4. Conclusions and further researches

Both experimental welded joints are visually free of defects. Regarding chemical composition, for joint made with ER309 filler participation of base material is higher, indicated by carbon diluted from ram steel. That indicates a stronger weld compared with classical ER308 filler.

As a result of chemical composition difference between the two joints, we have a difference also in steel microstructure. This difference is in ferrite content: 2.65% for ER308 and 8.49% for ER 309.

The research is continued in the sense of process experimentation, key factors recorded are:

- Lifetime of ram;
- Aspect of dummy block and weld (corrosion).

5. References

- [1] <https://www.engineering.com/AdvancedManufacturing/ArticleID/15524/New-Extrusion-Method-Makes-Magnesium-More-Practical-for-the-Auto-Industry.aspx>
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