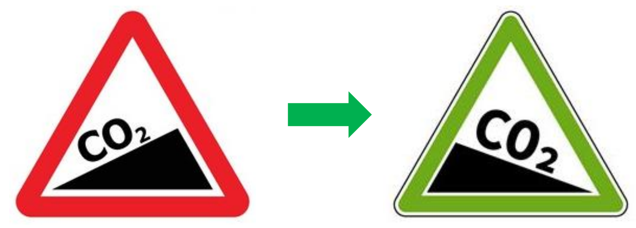

Processing and Properties of Press-Hardened Low-Density Steels

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Abstract

Experimental high carbon low-density steels (LDS, thickness of 1.7 mm) were processed by press-hardening using a combined tool. Press-hardening enables tailored properties within one component by thermomechanical processing—producing high strength in one region and higher ductility in another. Three LDS variants with different compositions were tested, and the hardness, microstructure, and mechanical performance of the distinct tool zones were evaluated. The steels could be processed without defects, and omega profiles were successfully formed. Tailored properties similar to conventional 22MnB5 boron steel were not observed; only very small differences between the cooled and heated parts of the tool were observed. Results indicate that LDS can be press-hardened and may offer potential for lightweight automotive applications.

Key words: press-hardening; hot stamping; high-strength steel; multiphase structure

Combined tool

- For hot stamped parts with different mechanical properties within one sheet
- Upper and lower part (**Fig. 1**)
- Heated (H), insulated (I), and cooled (C) part
  - H – solid; 7 heating cartridges (3 in upper; 4 in lower part)
  - I – 5 mm of insulation
  - C – 3D printed (DMLS; EOS M290; material MS1; cooling U-shaped channels; 14 in each part (7 inlet and 7 outlet holes)

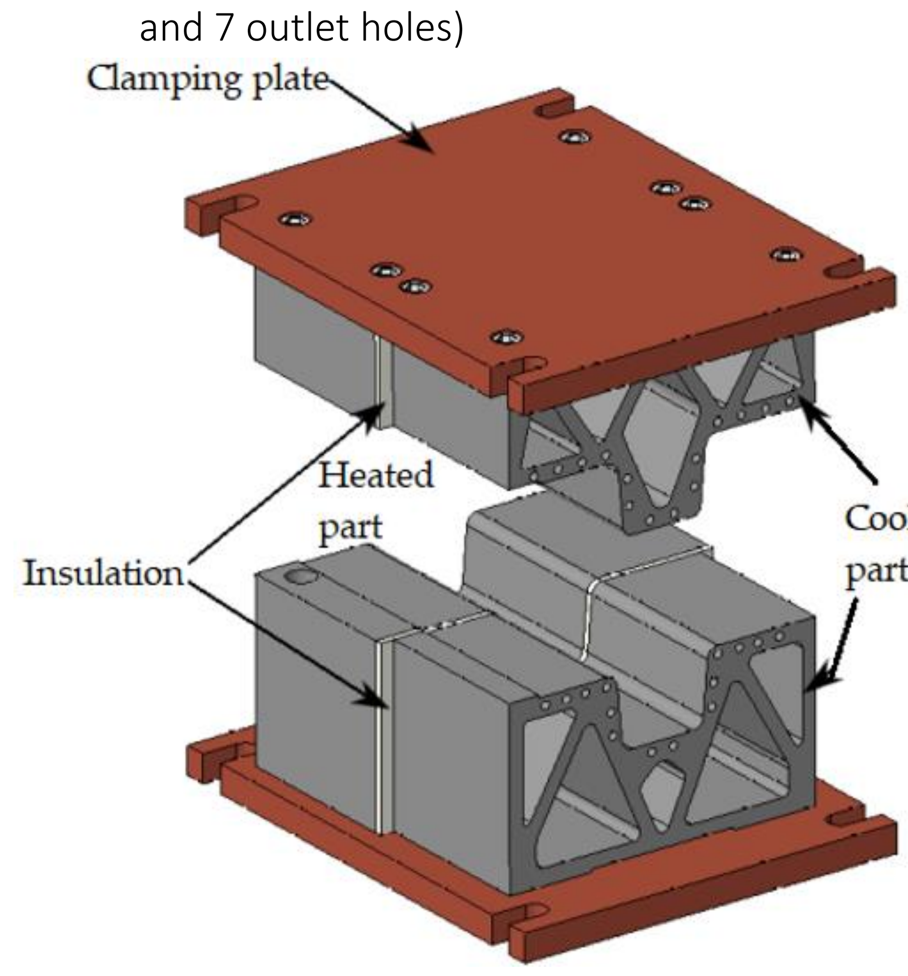

Figure 1. CAD assembly of the combined tool.

Experimental parameters

- Materials: high carbon LDS (**Table 1**)
- 210 x 240 mm sheets; thickness 1.7 mm
- Hot stamping + Tempering

Table 1. Chemical composition of used materials (wt. %).

Material	C	Si	Mn	Cr	Ni	Al	S	P
7SiAl (7%Al)	**0.69**	**0.58**	0.53	2.06	1.004	**7.06**	0.007	0.01
7Al (7%Al)	**0.73**	**0.12**	0.55	2.02	1.05	**7.06**	0.008	0.01
5Al (5%Al)	**1.07**	**0.16**	0.53	2.03	1.56	**4.97**	0.006	0.008

- Heating and austenitization at 950 °C for 15 minutes
- Transfer to the combined tool with 250/285/50 °C at the heated part and 20 °C at the cooled part
- Hot stamped and left in the tool for a certain period of time (10 and 30 s), then removed and freely cooled in the air, then half of the sheet was tempered (**Fig. 2**)

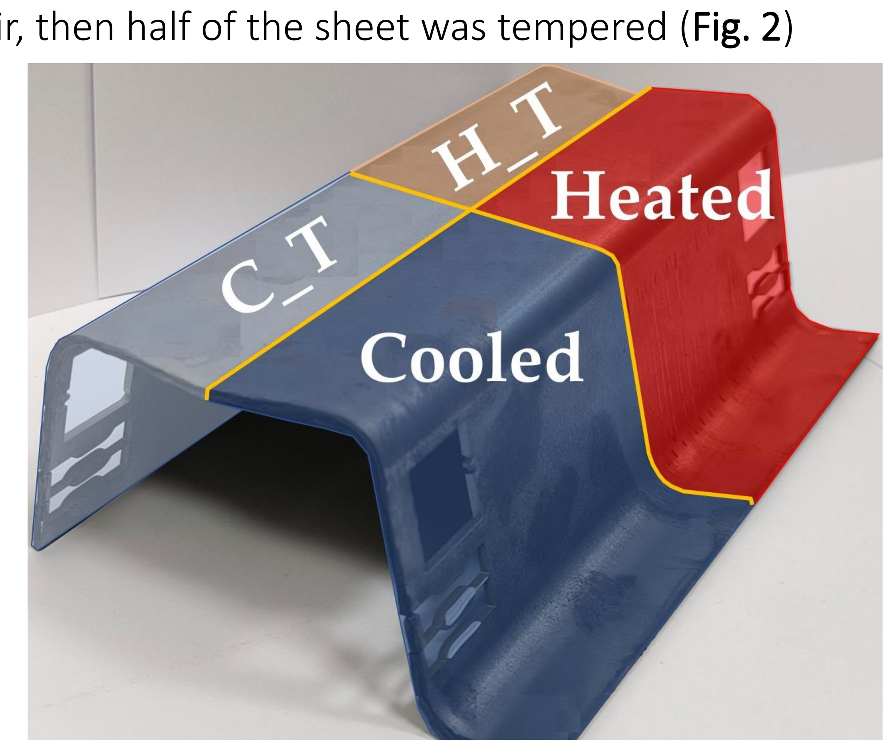

Figure 2. Final shape of the omega profile from the combined tool. Steel 7Al (cut and sampled). Cooled part in the foreground; heated part in the background. Left part tempered; right part untreated after press-hardening.

Equipment used for evaluation

- Olympus light microscope
- Scanning electron microscopy (SEM) Tescan VEGA 3
- Tensile test on a ZWICK Roel Z250 on mini tensile specimens with an active length of 5 mm and a cross-section of 2 x 1.2 mm (according to ČSN EN ISO 6892-1 method A)

Results

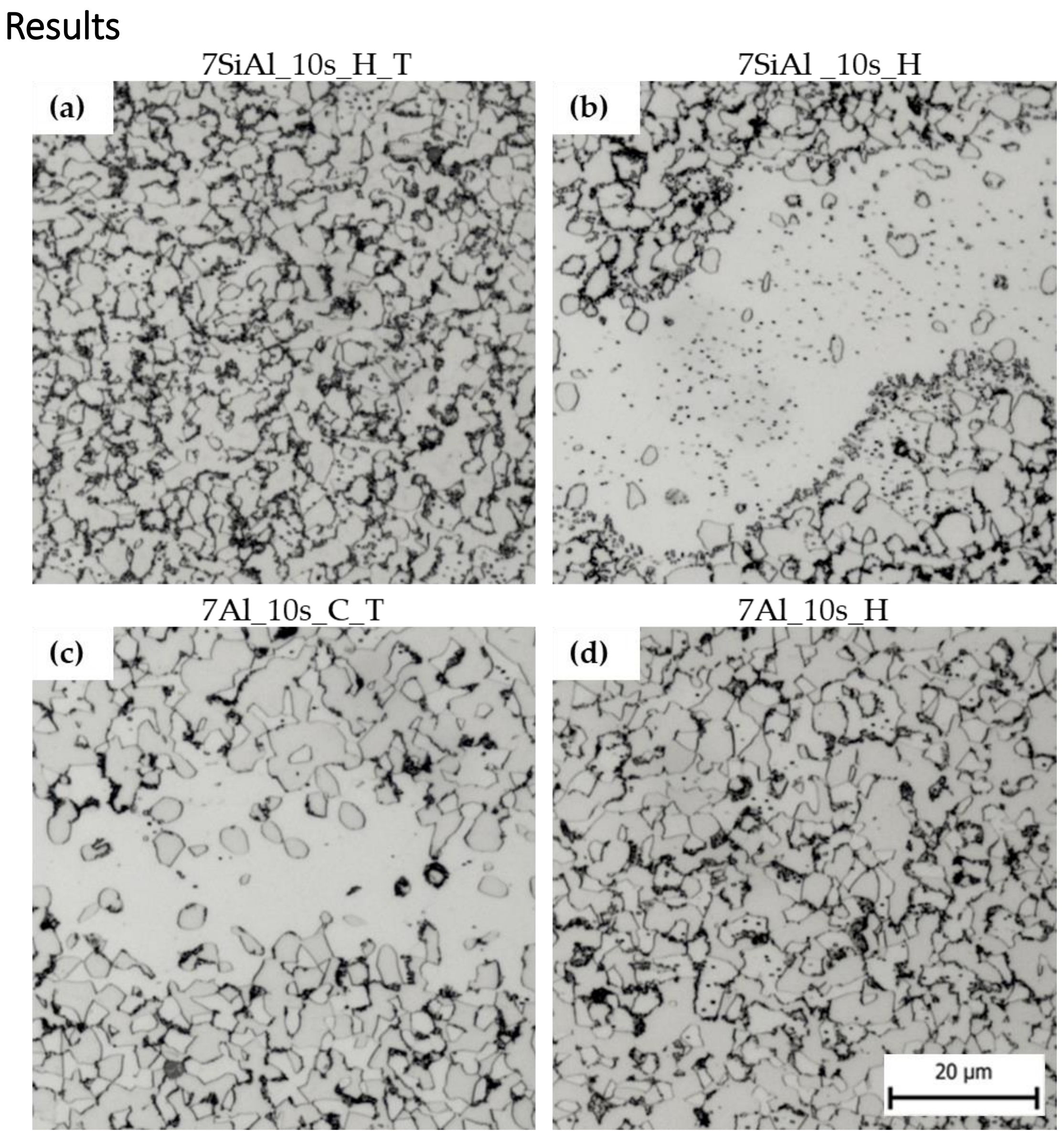

Figure 3. Microstructures of 7SiAl and 7Al after hot stamping from optical microscope.

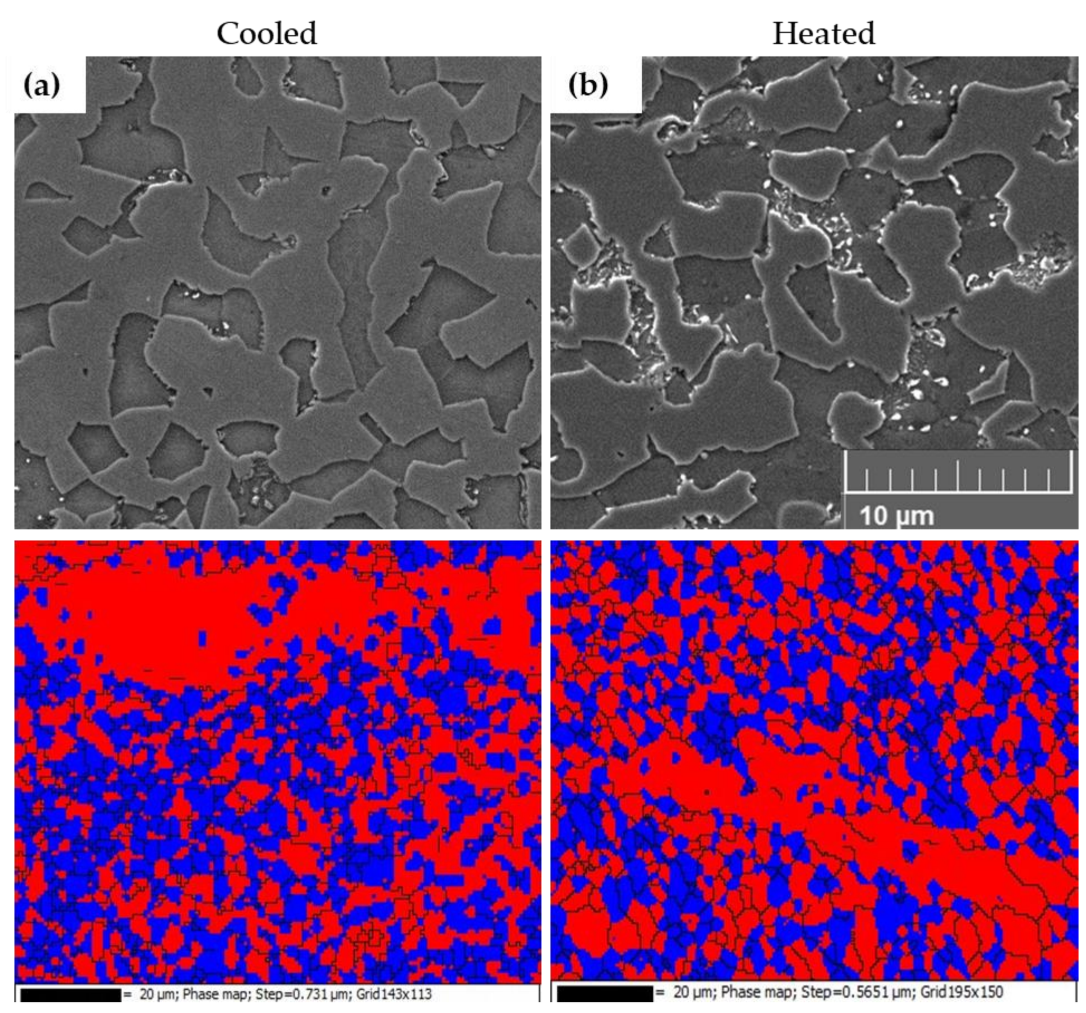

Figure 4. Microstructures of 7Al after hot stamping from SEM Tescan VEGA 3; including EBSD (a + c) cooled; (b + d) heated. Red = BCC; blue = FCC.

- 7SiAl + 7Al (**Fig. 3, 4**)
  - Very similar microstructures consisting of mostly ferrite, austenite (up to 55 %) and carbides, UTS around 1150 MPa (**Fig. 5**)
  - The effect of tempering is negligible; tempering is not necessary, hardness ca 350 HV10

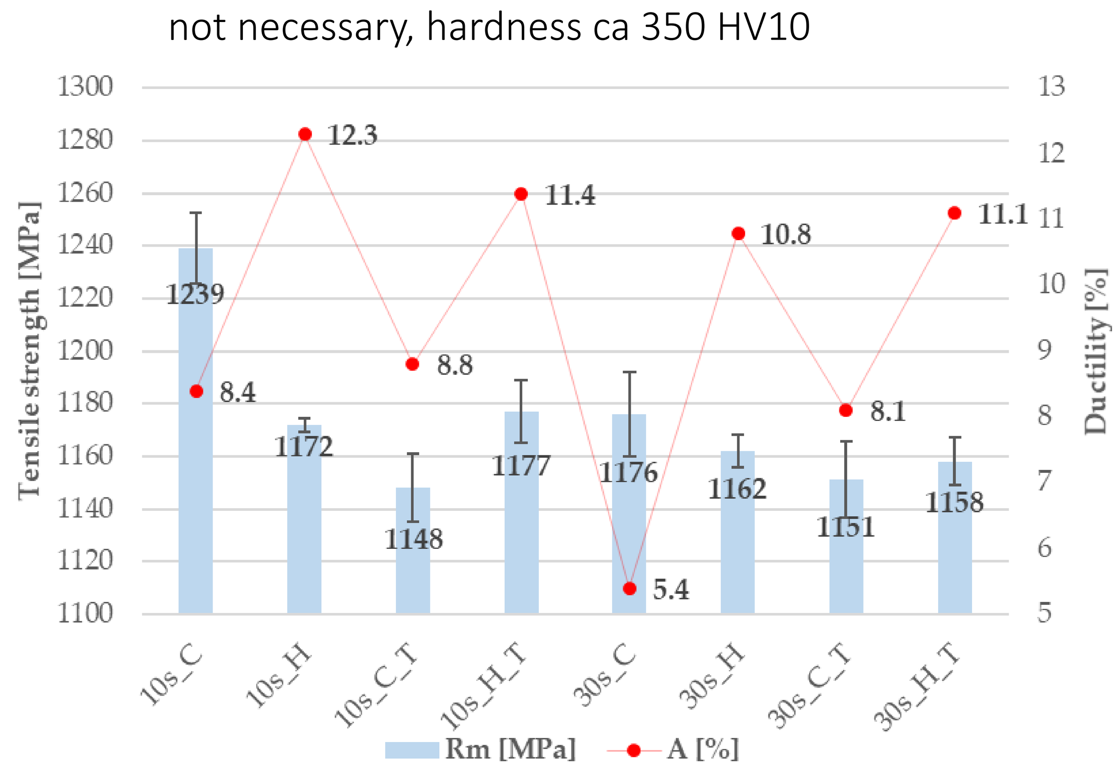

Figure 5. Mechanical properties of 7Al steel (cooled (C) and heated (H) part with or without tempering (T)).

- 5Al (**Fig. 6, 7**)
  - After press-hardening, the microstructure is martensitic and very brittle, hardness ca 660 HV10
  - After tempering, the microstructure becomes tempered martensite with increased ductility, UTS reaching up to 2200 MPa (**Fig. 8**), ca 700 HV10

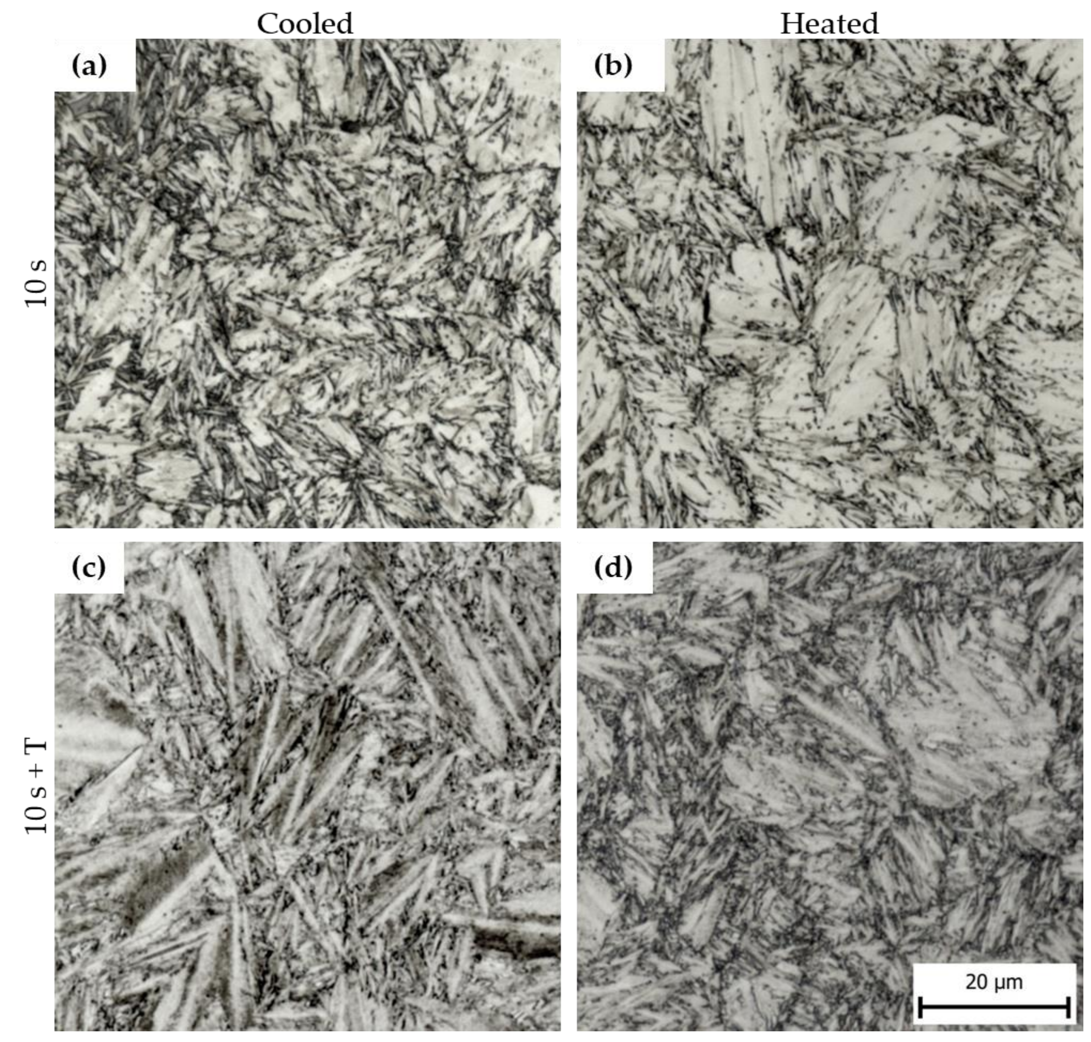

Figure 6. Microstructures of 5Al after hot stamping from optical microscope.

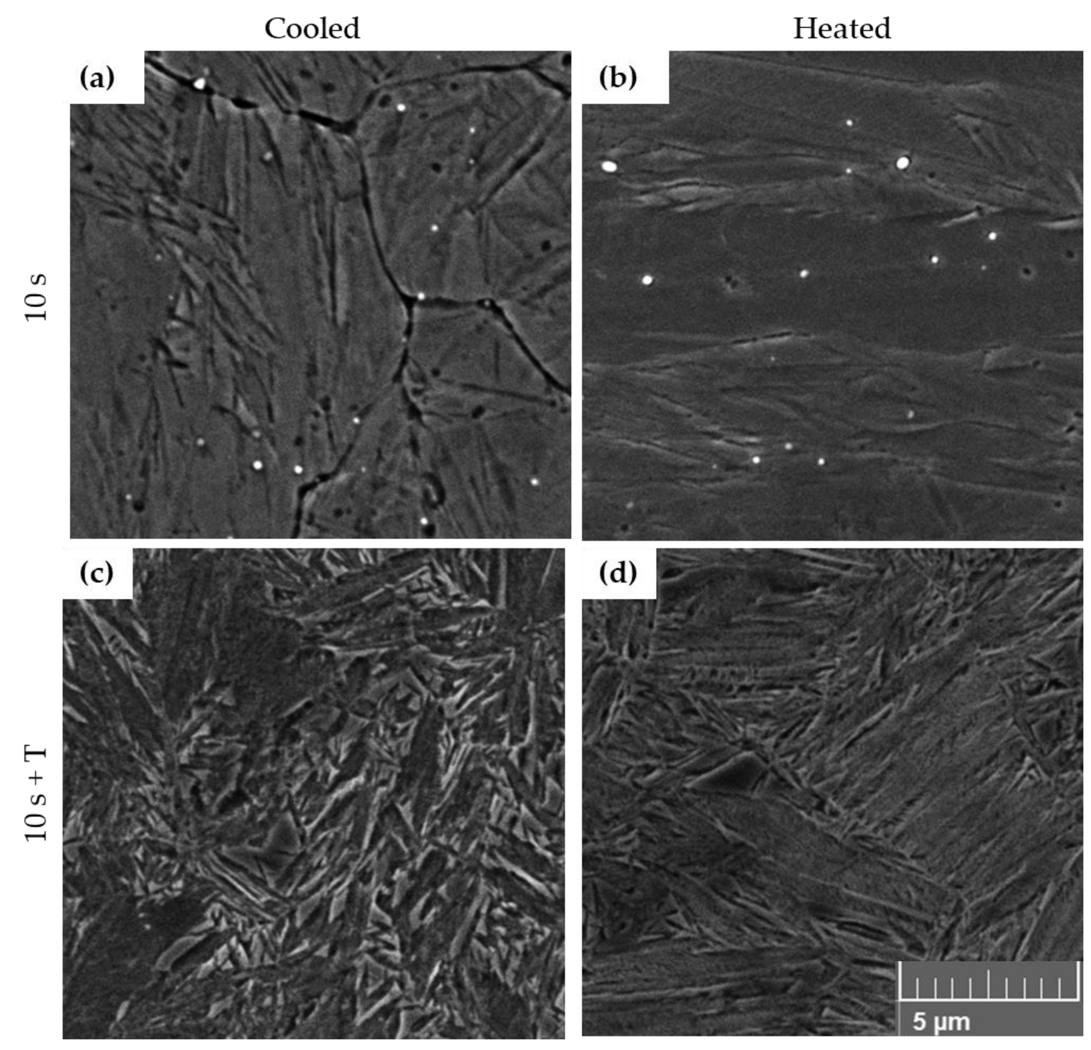

Figure 7. Microstructures of 5Al after hot stamping from SEM SEM Tescan VEGA 3.

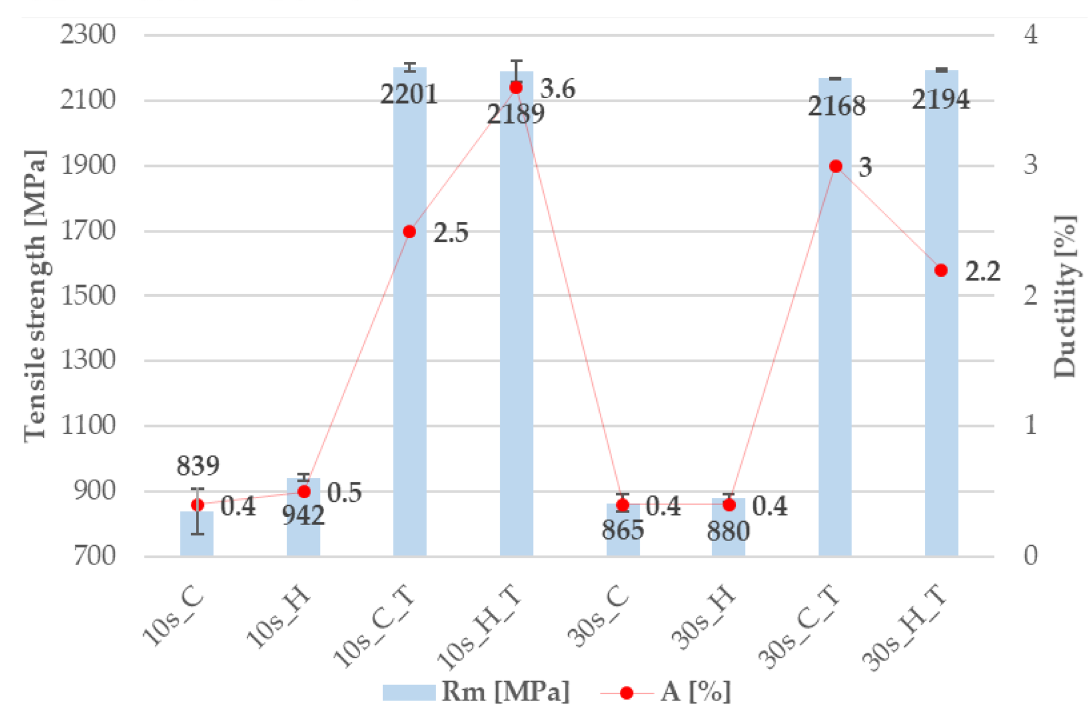

Figure 8. Mechanical properties of 5Al steel (cooled (C) and heated (H) part with or without tempering (T)).

Conclusion

Low Density Steels, which exhibit approximately 10% lower specific weight compared to conventionally used steels, were processed using the press-hardening method. The processed materials showed no undesirable defects. Although tailored properties were not achieved, there is potential for application, particularly when followed by tempering. This is evident in material 5Al, which demonstrated a significant increase in both UTS [MPa] and elongation [%]. The effect of higher tempering temperatures is currently under further investigation.

Material	Part	Rm [MPa]	A [%]	HV10	Regime
7SiAl	C	1144	8.4	355	10 s
	H	1201	10.2	375	
7Al	C	1239	8.4	345	10 s
	H	1172	12.3	348	
5Al	C	2201	2.5	692	10 s + T
	H	2189	3.6	700	

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