ANALYSIS OF THE EXPERIENCE OF MANUFACTURING METAL STENTS FROM DIFFERENT ALLOYS USING TRADITIONAL AND ADDITIVE TECHNOLOGIES

SERHII ADZHAMSKYI[1,2], GANNA KONONENKO[1,3], ROSTYSLAV PODOLSKYI[1,3], ELENA SAFRONOVA[3], SERHII BADUK[1]

1. LLC "Additive Laser Technology of Ukraine"
2. Institute of Transport Systems and Technologies of NAS of Ukraine
3. Iron and Steel Institute of Z.I. Nekrasov of NAS of Ukraine

Metal stents of the first generation were made of 316L steel, this material became widely used. Over time, they mastered the production of second-generation stents from the Ti6Al4V alloy, the latest generation products are made from CoCrMo glory. In recent decades, additive manufacturing methods (SLM and SLS) have made it possible to achieve high product quality and found their application, including in the manufacture of stents. A comparative analysis of the chemical composition and mechanical properties of the specified alloys and studies on the cytotoxicity of these materials made by casting, mechanical processing (milling), SLM and SLS were performed. It is shown that biological aspects and mechanical properties in laboratory conditions are influenced by the choice of production technology, heat treatment and microstructure of materials.

Keywords: railway rails, bainetic steels, chemical composition, microstructure

The most common traditional materials used for the manufacture of metal stents of the first generation are stainless steel (316L) [1], the second generation – titanium alloys (Ti6Al4V) [2], cobalt-chromium-molybdenum alloys (CoCrMo) are currently used, the chemical composition given in the table 1, mechanical and operational properties – in table. 2. The latest alloys have better corrosion resistance compared to other metals and high impact toughness, high wear resistance and higher hardness (HV=350) than other alloys and polymers. CoCrMo alloys are classified as hard-to-cut materials because they have several characteristics, such as high hardness, low thermal conductivity, high wear resistance, and strain hardening, that contribute to poor machinability. Although this alloy is similar to a titanium alloy in terms of its properties, research on the mechanical processing of CoCrMo alloys is still insufficient [3].

Table 1. The actual chemical composition of the experimental melts, wt.%.

Material	Chemical element									Ref.
	C	Si	Mn	Cr	Ni	Mo	V(W)	Al	Fe	
316L	0.01	0.6	0.7	17.7	12.6	2.3	–	–	base	[4]
Ti6Al4V*	0.10	–	–	–	–	–	4.03	6.21	0.04	[2]
CoCrMo**	0.01	1.2	–	26.7	–	6.3	(5.1)	–	0.11	[5]

Note: *– Ti-base, ** – Co-base

Table 2. Mechanical properties of materials.

Material	Mechanical properties				Ref.
	σ_B, MPa	$\sigma_{0,2}$, MPa	δ_5,%	Ψ, %	
316L	615.4	376.5	59.77	64.04	[6]
Ti6Al4V	1281	–	15.12	10.07	[2]
CoCrMo	1060	–	7.20	6.10	[5]

It should be noted that in work [7], in addition to the different chemical composition among the specified alloys, they were produced by four different methods: cast, milled, SLM and SLS. Based on the results of the study, the samples of CoCrMo alloys produced by four methods, together with pure titanium (Ti) and Ti6Al4V, were evaluated for the mechanical properties and structure of the material in terms of yield strength, elongation after fracture, hardness and microstructure.

All investigated materials [7] demonstrated non-cytotoxic effects, although the most active inflammatory response by cells exposed to the materials was observed for cast and SLS CoCrMo materials. In general, CoCrMo produced by the SLM method showed the highest mechanical properties. Biological aspects and mechanical properties in laboratory conditions are influenced by the choice of production technology, heat treatment and microstructure of materials. Further clinical studies are needed to evaluate these results [8].

1. *Mani G., Feldman M.D., Patel D. and Agrawal C.M.* Coronary stents: A material perspective. // Biomaterials. – 2007. – № 28. – P. 1689– 1710.
2. *Adjamskiy S.V., Kononenko G.A. and Podolskyi R.V.* Influence of heat treatment of specimens from Ti6Al4V manufactured by the technology of selective laser melting on structure and mechanical properties // The Paton Welding Journal. – 2022. – № 9. – P. 21–26.
3. *Saravanan R., Hamidon R., Murad N.M. and Zailani Z.A.* Machining of cobalt chromium molybdenum (CoCrMo) Alloys: A Review. Intelligent manufacturing and mechatronics. – Singapore: Springer, 2021. – P. 413-424.
4. *Adjamsky S. V., Kononenko G. A., Podolskyi R. V., Baduk S. I.* Research efficiency electrochemical polishing variable section samples with different roughness of steel AISI 316L, manufactured by technology of selective laser melting. // Aerospace technic and technology – 2021. – 170. P. 66–73. (in Ukrainian)
5. *Adjamskiy S., Kononenko G., Podolsky, R. and Baduk S.* Studying the influence of orientation and layer thickness on the physico-mechanical properties of Co-Cr-Mo alloy manufactured by the SLM method // Sci. Innov. – 2022. – 18. P. 85–94.
6. *Adjamsky S.V., Podolskyi R.V. and Kononenko G.A.* Investigation of plastic properties of AISI 316l steel by method of registration of macrolocalization fields // System technologies – 2021. – 4. P. 3–11. (in Ukrainian)
7. *Kassapidou M., Hjalmarsson L., Johansson C.B. et al.* Cobalt-chromium alloys fabricated with four different techniques: Ion release, toxicity of released elements and surface roughness // Dent. Mater. – 2020. – 36. – P. 352-363.
8. *Kassapidou M., Franke S.V., Johansson C. et. al.* Cobalt-Chromium alloys in fixed prosthodontics; investigations of mechanical properties and microstructure // J. Prosthet. Dent. – 2023. – in press. https://doi.org/10.1016/j.prosdent.2023.05.005