13th International Research/Expert Conference
„Trends in the Development of Machinery and Associated Technology“
TMT 2009 Hammamet, Tunisia, 16-21 October 2009

NEW MATERIALS AS BASE FOR DEVELOPMENT OF MODERN INDUSTRIAL TECHNOLOGIES

Mirsada Oruč
Milenko Rimac
Omer Beganović
University of Zenica – Institute of Metallurgy "Kemal Kapetanović" Zenica
Travnička cesta 7, Zenica
Bosnia and Herzegovina

Alen Delić
TMD A.i. Gradačac - Nimonic d.o.o.Zenica
Travnička cesta 7, Zenica
Bosnia and Herzegovina

ABSTRACT
The paper provides an overview of experimental produced special high-alloyed steel, nickel and cobalt superalloys and the technologies of their manufacturing. On the base of modern test methods was established dependence between microstructure, mechanical properties and usage conditions. This paper gives a description of optimization of alloys chemical composition and improving production technologies, so as improving of work characteristic of new or known materials. Application of metallic coatings is also the way for improving work characteristics of such materials.
Key words: High alloyed steels, superalloys, mechanical and microstructure properties, coating

1. INTRODUCTION
Technological and industrial development is possible only if adequate materials exist. Because of that a certain attention should be dedicated to development of new materials or improving work characteristics of existing materials if such materials are wanted to be used in the more demanded conditions [1].
Researches which were carried out in recent years enabled better understanding of relations between microstructure and properties of metallic materials. Mentioned created prerequisites for predicting properties of the other materials and technical possibilities of their application.
Institute of metallurgy "Kemal Kapetanović" Zenica (Institute) deals with research and development of new materials used for manufacturing of structural elements which work in complex exploitation conditions (high static and dynamic loads, high temperature, creep). These materials have broad application but because of high prices they are mainly used in modern industrial branches (aircraft and auto industry, rocket technique, electronic, medicine, heat exchangers). For production, processing and testing of such materials modern plants and high-sophisticated research and laboratory equipment are being used. Institute has got needed equipment for research and development of such materials. Some of these materials are manufactured only by special producers having licenses or inaccessible and protected technologies. So if such materials are wanted to be produced an own technology has to be developed on the base of required properties, technical demands or data from standards or corresponding specification.
Permanent demands for improving mechanical and exploitation properties of new materials stimulate additional researches in this area. Modern trends for improving material characteristic besides process

of powder metallurgy and new thermo-deformation processes; prefer process of making metallic coatings on alloy surface.

2. MATERIALS PRODUCED AND HOMOLOGATED AT THE INSTITUTE

On the base of performed researches the next materials are produced and homologated:

Special high-alloyed steel

- Austenitic stainless steels: AISI 316 LN i Nitronic 60
- Dual phase austenitic-martensitic stainless steel with precipitation hardening PH 17 7
- High-strenght maraging steels: 18Ni (250) i 18Ni (350)

Superalloys

- Iron base superalloy A 286
- Nickel-base superalloys: cast-Inco 713C and wrought-Nimonic 80A i Nimonic 90
- Cobalt base superalloy HS 25

In table 1. the base characteristic of produced and homologated materials are given (main alloying elements, tensile properties, microstructure).

Table 1. Base characteristic of materials

Material	Chemical composition, %								Tensile properties		Microstructure*
	C	Cr	Ni	Co	Ti	Al	Mo	Ostali	Rm, MPa	A, %	
AISI316LN	0,03	17,5	12,5	-	-	-	2,5	N	700	40	A + K
Nitronic 60	0,06	17,5	8,5	-	-	-	-	Mn,N	750	65	A + K
PH 17 7	0,08	16,5	7,5	-	-	1,2	-	-	1420	10	A+M+*ic*+K
18Ni (200)	0,01	-	18,0	8,5	0,2	0,1	3,3	-	1960	11	M_{Ni}+ *ic* +K
18Ni (350)	0,01	-	18.0	12,5	1,6	0,1	4,8	-	2450	10	M_{Ni}+ *ic* +K
A 286	0,04	15,0	25,5	-	2,10	0,25	1,3	B	1250	20	A+ *ic* +K
Inco 713 C	0,12	13,5	bal.	-	0,9	6,0	4,2	Nb, B	1110	30	A+ *ic* +K
Nimonic 80A	0,06	20,0	bal.	-	2,4	1,4	-	B	1100	40	A+ *ic* +K
Nimonic 90	0,07	20,0	bal.	18,0	2,5	1,5	-	B	1200	35	A+ *ic* +K
HS 25	0,05	20,5	9,5	bal.	-	-	-	W	890	35	A+ *ic* +K
NOTE*A–austenite, M–martensite, M_{Ni}–nickelmartensite, K–carbonitrides, *ic*–intermetallic compound $Ni_3(M)$											

2.1. Special high alloyed steels

Austenitic stainless steel AISI 316 LN with increased content of nitrogen is developed for medical purposes. Steel Nitronic 60 with increased content of manganese, silicon and nitrogen [2] is characterized with good galling and corrosion resistance and it can be used for production elements of turbochargers working on temperatures around 700^{o}C.

Dual phase austenitic-martensitic stainless steel with precipitation hardening PH 17 7 gives possibility of programming properties through regulation of austenite and maretensite content. Additionl regulation properties of this steel is possible through precipitation hardening of austenite. As this steel also has spring properties it is used in aircraft industry. Maraging steels 18Ni (250) and 18Ni (350) have very high values of tensile strength and impact energy [3]. These properties are achieved by precipitation of intermetallic phase *ic*, $Ni_3(M)$ in nickel-martensite carbonless matrix. Because of their extraordinary characteristic these steels are used in rocket and aircraft industriy.

2.2. Superalloys

Nickel base superalloys (cast and wrought), because of precipitation of coherent *ic* phase $Ni_3(Al,Ti)$ in nickel-austenite matrix, posses high values of static and dynamic mechanical properties and creep strength, and also needed corrosion and heat resistance. Because of that superalloys are used for production very loaded structural parts working at high temperatures up to 1100^{o}C in aircraft technique and for making parts of turbochargers in car engines.

Cobalt base superalloy HS 25 has similar properties as nickel base superalloys. Alloy HS 25 is used for production of medical implants and parts in air industry.

3. RESEARCH METEDOLOGY AND EXPERIMENTAL PRODUCTION

Technical requirements that a material has to satisfy during exploitation are initial base at research and development of new materials and corresponding technologies. Mentioned above is base for designing of chemical composition of the alloy. For designing alloys composition certain alloying elements are available. Each alloying element particularly and in interaction with the others has influence on forming of the microstructure and with that it has corresponding influence on the alloy properties. As it can be seen in table 1, for mentioned alloys, the same elements are mainly used but in different quantities and proportions.

On the base of an alloy chemical composition the technology of production of liquid metal, technology of hot, worm or cold working and technology of heat treatment are designed. Production of liquid metal is the most important phase which usually includes combination of different plants. Vacuum-induction melting and casting technology followed with electron-beam remelting or electro-slag remelting process (ESR) enables production of liquid metal with extremely low content of carbon, nonmetallic inclusions and gases.

Austenitic stainless steel and maraging steels are well formed in hot, warm and cold conditions, so standard technologies of processing can be applied. Superalloys are deformed more difficult than most other metallic materials. Because of that for defining technology of their plastic deformation it is needed to perform examinations of plasticity of corresponding superalloy with precise definition of all working parameters (temperature, force, reduction, working rate).

4. RELATIONS BETWEEN MICROSTRUCTURE AND PROPERTIES

The basic model of researches is designing material microstructure that will assure required mechanical and exploitation properties. Characteristic microstructures of some analyzed alloys, obtained on electron and optical microscopes, are given on figures 1. to 6.

Grainboundary carbonitrides of austenitic stainless steel AISI 316 LN increase tensile strength and creep resistance but binding of carbon and nitrogen with chromium decreases resistance to grainboundary corrosion (Figure 1). Balancing content of elements stabilizing ferrite and elements stabilizing austenite it is possible to achieve austenitic structure without undesirable δ ferrite in steel Nitronic 60 (Figure 2). Austenitic carbonless matrix of maraging steel which has excellent plasticity can be hardened to high values by forming of iron-nickel lath martensite matrix and by precipitation of coherent *ic*-phases (mainly $Ni_3(Mo)$) (Figure 3). Precipitation of coherent intermetallic phase Ni_3Al in austenitic nickel-matrix of cast superlalloy Inco 713 C enables an acquirement of significant creep resistance which is basic prerequisite for working at high temperatures (Figure 4). Similar structure is characteristic for wrought superalloy Niminic 80A which has less creep resistance because of precipitation of less quantity of *ic* phase $Ni_3(Al,Ti)$. Mentioned above is a result of presence of less quantity of elements (Al, Ti) which participating in its forming (Figure 5).

In the figure 6. it is given the microstructure of cast iron base superalloy A 286 with coating NiCrAlY produced by Diamond–Jet (DJ) technology. Depending on applied heat treatment it is possible to achieve surface (coating) hardness up to 48 HRC that is significantly higher than hardness of substrate in cast and hardened condition

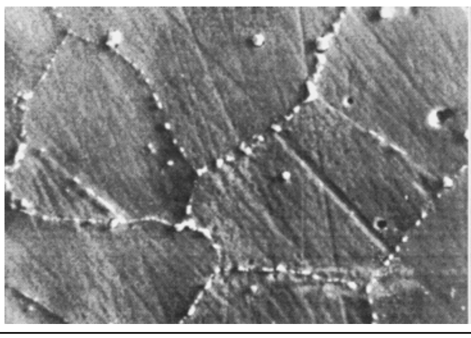

Figure 1. Steel AISI 316 LN (x 2000), Austenite and carbonitrides

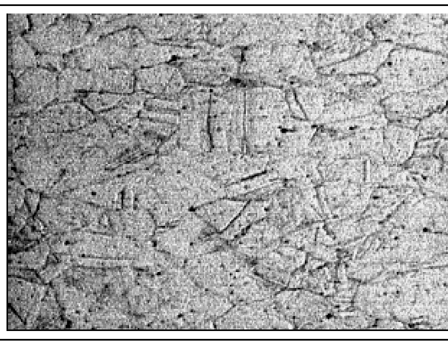

Figure 2. Steel Nitronic 60 (x145), Austenite without δ ferrite

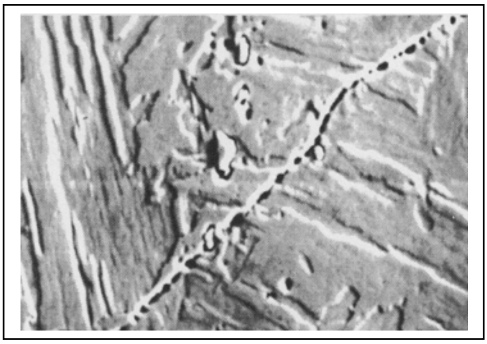

Figure 3. Maraging steel 18Ni (250) (x 4500), Nickel-martensite and ic

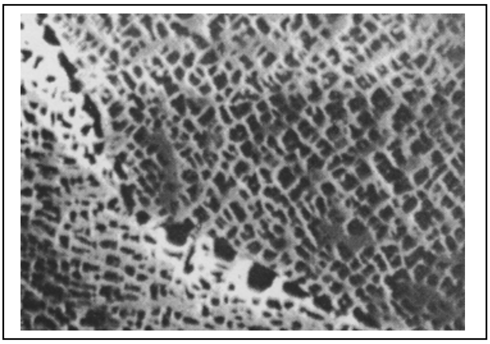

Figure 4. Inco 713 C (x10000), Nickel-austenite + ic

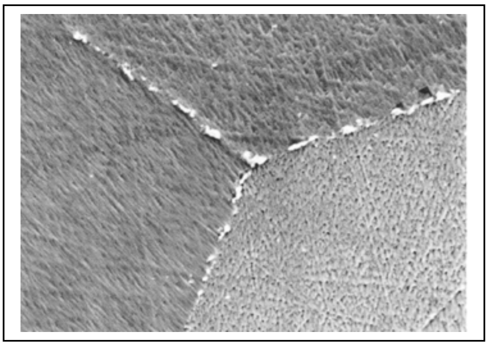

Figure 5. Nimonic 80A (x 3500), Nickel-austenite and ic

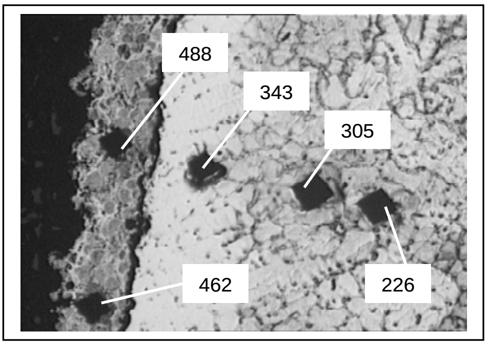

Figure 6. Cast superalloy A 286 (x75) with coating NiCrAlY and hardness HV 0.5
(Heat treatment 1080°C/8h AC +720°C/16h AC)

5. CONCLUSION

Detailed experimental and laboratory researches have enabled production of number of modern materials which after homologation can be used in different industrial technologies.

Our own technologies were designed depending on required properties. Particular properties of some alloys were improved with the aim of achievement better functioning of the structural parts in exploitation. With the same aim development of technologies of the depositing metallic coatings represent one of possible ways for significant improving of exploitation characteristic of existing materials.

6. REFERENCE

[1] Oruč M., Rimac M.: Metalic Materialls Development for Advanced technologies, 7th Scientific/Research Symposium with International Participation, Metallic and Nonmetallic Materials, Zenica, Bosnia and Herzegovina, 2008.,
[2] Beganović O., Muminović B.: Optimization of Chemical Composition Austenitic Stainless Steel Nitronic 60 with the Aim of Prevention δ Ferrite Formation, 7th Research/Research Symposium with International Participation, Metallic and Nonmetallic Materials, Zenica, Bosnia and Herzegovina, 2008.,
[3] Rimac M., Spaić B.: Mastering of Forging Plastic Processing of maraging steel 18Ni (350), Institute of Metallurgy "Kemal Kapetanović" Zenica, 1989.,
[4] Fakić B., Kratina E.: Research of Influence of making Technology and Alloying Elements on Characterisic of Superalloys Based on Iron-A 286, 7th Research/Research Symposium with International Participation, Metallic and Nonmetallic Materials, Zenica, Bosnia and Herzegovina, 2008.