EXPERIMENTAL RESEARCH PROGRAM REGARDING THE INFLUENCE OF THERMO-TIME TREATMENT OF MULTICOMPONENT Ni-BASE MELTING ON THEIR PROPERTIES IN SOLID PHASE

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Over the past decades has begun to increasingly pay attention to properties and structure of metals and alloys in liquid phase, the motivation being both scientifically and practically [1]. Particularly, especially in recent years, it has been demonstrated through the numerous studies, that the structural characteristics of different metallic melting might heredity influence, sometimes dramatically, the properties of the alloys after solidification. That possibility constitutes, in fact, a treatment in liquid phase suggestively named Thermo-Time Treatment. In this respect, a complex experimental research program is proposed for a Ni-base alloy, used in hot and high corrosive areas of aircraft engines.

Keywords: Thermo-Time Treatment (TTT), microstructure, Ni-alloy, aircraft engines.

1. Introduction

Turbine industry for power plants but also the manufacture of Turbo-Jet engine components from civil and military aeronautical industry have put the issue of finding new materials to withstand both high temperature application and environmental factors intensely corrosive [3],[5]. Research in this area has been channeled primarily upon the following two categories of materials:

-Superalloys - refractories and corrosive resistant based on transition metals.

-Materials with very high refractivity: have been taken as a base material with a very high melting point, such as chromium, refractory metals (Mo, W, etc.), but also some ceramic materials.

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Internationally, consistent efforts and investment research focused mainly on the material in the first category, i.e. superalloys - refractories and corrosive resistant based on transition metals. The main transition metals basically used in the chemical composition of these super alloys are as following, in order of importance: nickel, cobalt and iron.

Complex researches of thermochemical and thermomechanical processes undergone by such a super alloy, on the one hand, researches in powder metallurgy, on the other hand, have revealed a possible doubling of components load resistance of Turbo-jets engines under temperatures of between 460 and 760 ^{o}C. These substantial improvement is a consequence of an increase in the index of super plasticity, but most of all the resulted superfine crystalline grain with the high level of isotropic characteristics.

2. Experimental

2.1. Class-Base Super alloys

Material chosen for the experiments is classified as superalloy -based nickel, used in the aviation industry in hot and high corrosive areas of aircraft engines, more precisely in the composition of jets and engines, operating at high levels of:

- Temperature: over 540 ^{o}C (given to the region of mechanized guiding holes of the turbine to the temperature up to 1100 ^{o}C)
- Pressure; -longitudinal elongation: effort between 10,000-70,000 psi;
- Duration between two successive revisions: 12,000 hours.

Super alloy used in the experimental programs proposed: **MSRR 7045 (Materials Super alloys Rolls-Royce 7045).**

The main brands of superalloys that are part of this class and in a uniform manner, as casting alloys (intended for precision molding), are played according to the table 1:

Table 1

Class -Ni Base Super alloys

Mark	Chemical Composition												French Standard
	C	Si	Mn	Cr	Mo	W	Al	Co	Ti	Fe	B	Others	Ni	
MSRR 7045	≤0,1	≤0,6	≤0,6	20-23	9-10,5	≤0,6	0.7-0.9	≤1	2,4-2,8	≤0,5		Ag ,B i,Pb =0,0016	b	P.E.R. C 130
MSRR 7040	0,06	≤0,3	≤0,2	20	5,80		0.5	20	2,20	≤0,5	50 ppm	Zr ≤ 200 ppm	b	P.E.R. 263 F
MSRR 7047	0,15	≤0,2	≤0,2	15,5	8,5		4,1	10	3,5	≤0,5	60 ppm		b	P.E.R. C 1023

2.2. Microstructure:

-austenite FCC - face-centered cube space lattice **(phase γ, matrix alloy):**

Continuously appearance of it represents an FCC austenite phase in nickel base, which usually contains a high percentage of solid solutions of some components, such as Co, Cr, Mo, W, Ti, Al or Fe.

These components differs from the nickel with 1- 13% in atomic diameter.

Because pure nickel is not endowed with a high elasticity module or diffusion (two factors characterizing creep phenomena and tearing), γ matrix contributes to the reliability of metal material in the most severe environmental conditions and thus superalloys based Ni can be used at temperatures in the range $0.8T_{melt}$ and endurance times of about 100,000 hours at the usual operating temperature.

- **γ' phase**: phase precipitating major type (Ni, Co) 3 (Al, Ti) that can appear as a phase of grain boundary: Al and Ti are added to the amounts calculated separately in superalloys or to substitute for each other in order to precipitate fractions important dosing phase γ ' crystallized all the CFC system, precipitation that is occurring in a coherent manner with austenite in the matrix.

- **Carbides**: primary or secondary type **MC:** $M_{23}C_6$, M_7C_3 (Cr_7C_3, mainly) and the M_6C that inhabits the grain boundaries (M-metal).

Carbides appear to prefer submission to grain in Ni-based super alloy, this being beneficial in terms of breaking resistance at elevated temperatures, according to majority of researchers in the field.

Intermetallic compounds geometrical (**TCP**, typologically close packed): they may be Laves phases, or μ or σ phases (vacancies compounds) which causes a sharp decrease for breaking strength and ductility.

All of these particularly complex phases are characterized by instability in the structural and thermodynamic sense: according to their genesis the individual phases within the super alloys microstructure are not in equilibrium, but they tend to evolve toward equilibrium with increasing temperature.

Many of these phases may change, depending on temperature and time-keeping at that temperature. This may constitute a prerequisite for the design study of a thermal time treatment (TTT), in the liquid phase, as the only possibility of heat “correction” intervention, taking into account the nature of the studied super alloy.

2.3. Stability of the Super alloy Surface

Properties involved here take into account the aggressiveness of the working environment of these components made from super alloys:

Oxidation: in manufacturing industry of Turbo jets the oxidation is defined as a super alloy reaction with oxygen in the presence of intermediate products resulting from the combustion of "clean" fuels, i.e. without contamination, such as Na, S and V.

A good oxidation resistance is obtained by forming a continuous thin films and which acts as a diffusion barrier and is not exfoliating during thermal cycle required by the operating environment of the engine.

Recently, the idea of small quantities of modifier has been taken into account: very small amounts of yttrium, lanthanum, and cerium led to the removal of burns and improved resistance to oxidation for many Ni and Co-based alloys or refractory steels (austenitic Fe-base alloys).

Corrosion at high temperatures (sulphating): refers to a particular aggressive attack resulted from a combined effect of usual oxidation process and the sulfur and other contaminants reactions which are contained in combustion air and/or proper fuel.

The main component as "guilty" of warm corrosion seems to be sodium sulphate, Na_2SO_4, which would finally dissolve protective oxide layer, making place for sulfur diffusion by this layer inside metal matrix.

Sulphating is generally correlated with the content of chromium from super alloy and with structural properties related to presence of sulphates.

Volatilization of Na_2SO4 above 980^oC makes sulphating at these temperatures to be replaced by oxidation only while at temperatures below 980 ^oC the effect of corrosion at high temperatures can become dominant with on the super alloy quality, consequently.

3. Integrated experimental program:

Starting from both micro-non-homogeneousness and structural non-equilibrium of the multicomponent melting, generally speaking, and continuing with the interconnection: metallurgical heredity - sensitive structural properties of melting versus - properties in solid phase the following experimental program has been proposed for the Ni-based MSSR 7045 super alloy as described in the figure 1, where:

VIF = Vacuum Induction (Melting) Furnace
$\mathbf{p_M}$ = samples for primary working
p_j = experimental melting samples
$\mathbf{T_{cr}\ (\sigma)}$ = critical temperature for TTT
TTT = Thermo-Time Treatment
R_m = Tensile Strength
$Rp_{0.2}$ = Proof Stress as the amount of stress that will result in a plastic strain of 0.2%.

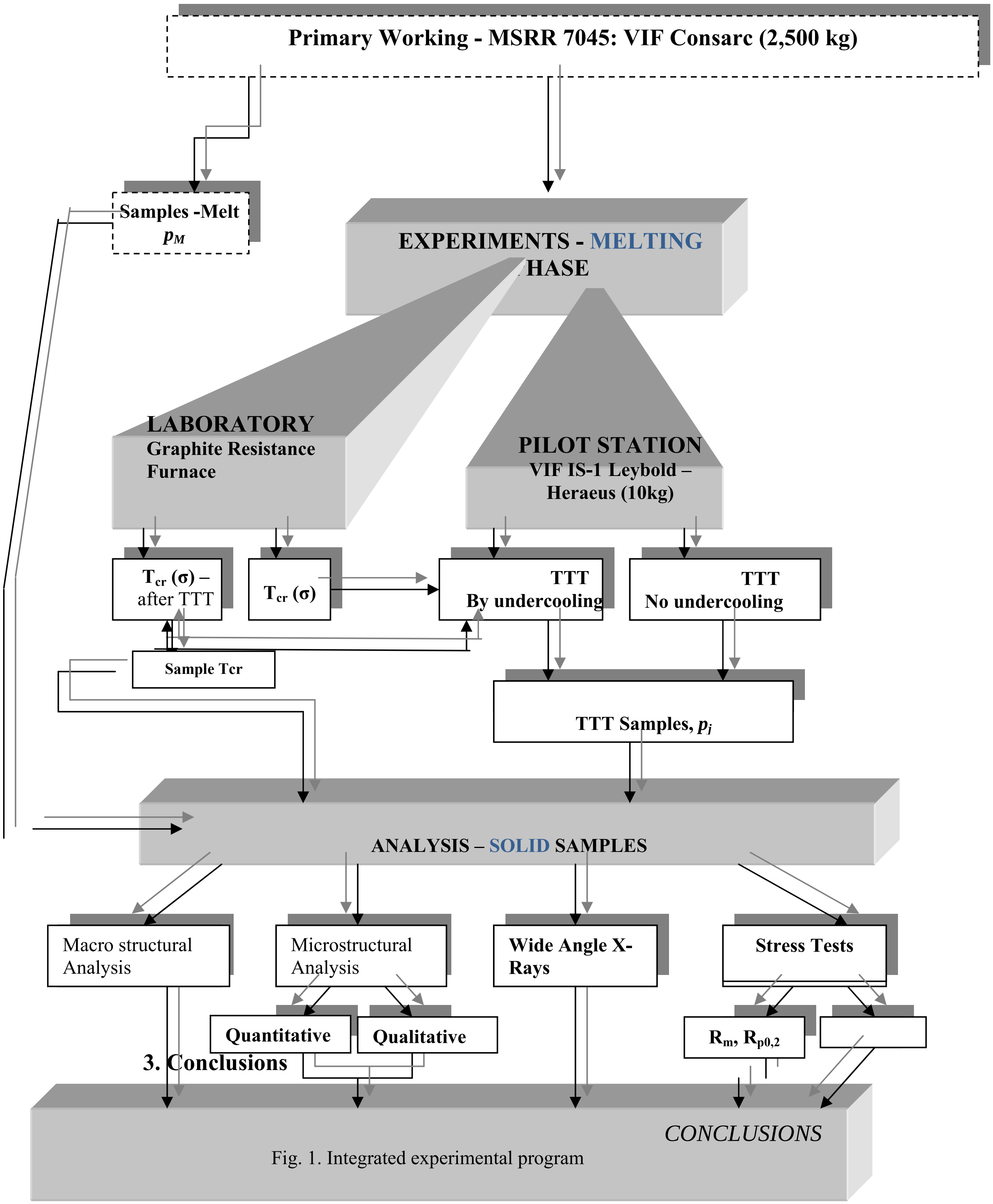

Fig. 1. Integrated experimental program

3. Conclusions

It can be said that the selection of a nickel base super alloy experimental programme in order to research some variations of Thermo-Time Treatment had the following main reasons:

1. Possible even duplication of tensile strength by obtaining small and uniform grain size with a high isotropy of their properties;

2. Idea of substituting a possible modification process of the superalloy structure by using heavy fusible particles (Titanium carbo-nitrides) or lanthanides in the aim of homogenization;

3. Idea to “exploit" the phase instability, shown above, from the following two points of view:

-improving the heredity of the solid product, therefore the possibility of a state as close as possible of the structural equilibrium or even a micro-homogenization in its liquid state precisely because of the instability of these phases.

It might be possible a smaller variety of close together orders resulting in optimized solid state, consequently.

The resulted solid metallic material could present a composition with an acceptable quantity of intermetallic phases, carbides with a certain size and shape supported qualitatively by the user at the end of the day;

- no heat treatment commonly used in the case of foundry alloys.

R E F E R E N C E S

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