
JOURNÉE
INNOVATIONS
MÉTALLURGIQUES
POUR L'INDUSTRIE
DE LA DÉFENSE
ÉCOLE MILITAIRE 5 PLACE JOFFRE 75007 PARIS
AMPHITHÉÂTRE DES VALLIÈRES - 8h30
29 03 18
IHEDN
AUBERT&DUVAL
DGA
Constellium
MINES SaintÉtienne
DGE
RNM
cea
ArcelorMittal
CIFAS
SAFRAN
THIOT INGÉNIERIE
GICAT
GICAN
FEDM
MINES ParisTech
NAVAL GROUP
A&M
hef groupe
SF2M
EUROSATORY
Groupe ERAMET

8h30 9h Accueil, café et échanges

OUVERTURE

9 h 9h15

Général Bernard de COURRÈGES D'USTOU
Directeur de l'Institut des hautes études de défense nationale (IHEDN)

9 h15 9h30

Georges DUVAL
Membre du conseil d'administration et du comité stratégique du groupe ERAMET

9h30 9h45

Jean-Loup HEUZE
Direction générale de l'armement (DGA)

9h45 10h

Pascal RAY
Directeur de l'École des Mines de Saint-Étienne

PRÉSENTATIONS TECHNIQUES #1

Modérateurs
Hubert SCHAFF (SF2M), Jacques LECADET (Aubert & Duval)

10h 10h30

AUBERT&DUVAL

"Développement des alliages à hautes performances pour l'industrie de l'aéronautique et de la défense"

10h30 11h

cea

"Mesure en ligne de la profondeur de pénétration d'un soudage laser"

11h 11h30
Pause-café et échanges

11h 11h30

ArcelorMittal

"MARS 600, un acier innovant dans la famille des blindages de très haute dureté"

12h 12h30

THIOT INGENIERIE

"THIOT INGENIERIE : un partenaire en Dynamique Rapide pour l'industrie de la Défense"

12h30 1400
Déjeuner Buffet et échanges

PRÉSENTATIONS TECHNIQUES #2

Modérateurs
Jean-Jacques MAILLARD (RNM) et Paul-Henri RENARD (CTIF)

14h 14h30

DGA MINES ParisTech

"Étude de la recristallisation au forgeage d'un acier inoxydable"

14h30 15h

NAVAL GROUP

"La fabrication additive à Naval Group : enjeux et perspectives"

15h 15h30

Constellium

"Les nouveaux développements aluminium pour l'industrie de la Défense"

15h30 16h

hef groupe

"Ingénierie des surfaces : des revêtements fonctionnels aux poudres pour la fabrication additive"

16h00 16h30
Pause-café et échanges

16h30 17h

SAFRAN

"Accélérer la maturation des solutions Matériaux et Procédés : un enjeu de compétitivité"

17h00 17h30

ONERA

Modélisation de la précipitation dans les superalliages base nickel et application à un disque de turbine haute pression

17h30 18h

RNM

CLÔTURE

Francois **MUDRY** (RNM)

METALLURGICAL INNOVATIONS IN DEFENSE INDUSTRY
Technical meeting organized march 18th by CEM (1), IHEDN (2), DGA (3) and ERAMET Aubert et Duval
Military School in Paris

This meeting knew a great success with 200 participants, with an important percentage of industrials (75%), showing the interest of the subject connected with the renewed interest for metallurgy. After an opening session introduced by the four organizers, ten conferences were presented, five on the main metallic materials used in Defense Industry, steels, nickel and aluminum alloys, three on the perspectives of evolution of these materials and two on the means of characterization.

Opening Session : Professor Jean Jacques ROCHE, head of Formation, Research and Development Department, presented IHEDN as an exchange place with formations in armament and defense economy, European sessions on influence diplomacy, and missions on national defense network. Georges DUVAL, member of Board of Directors and Supervisors of ERAMET Group, presented Aubert et Duval like a national partner of armed forces, with a strong know-how on the main metallic products : high strength steels, nickel, titanium and aluminum alloys, with doubling of powder metallurgy capacity, and the starting of a plasma furnace "Ecotitanium" for the remelting of titanium alloys scraps. Jean Loup HEUZE has presented for DGA the strong connection existing between metallurgy and armament industry in order to give the optimal performances of materials in mechanical characteristics, corrosion, impact, fatigue and ageing resistance, all in a concern of weight reduction and production in a reasonable cost. David DELAFOSSE, Research Director of ENSMSE, has presented the strong connection between this school and the CEM, with an important development of metallurgical studies in the Material Department, mainly in the domain of durability and additive manufacturing.

Metallic materials used in Defense Industry : Jacques LECADET, has presented for Aubert et Duval the main families of metallic materials used for Defense Industry : high strength steels (MLX®17, MLX®19 for landing gears, ML340 for aircraft motors shafts, ARMAD® for arm tubes of small caliber) nickel base alloy AD730® more resistant in temperature than IN718 for aeronautic turbines. Aubert et Duval develops also additive manufacturing, working on process and deposition speed : melting of wire and powder, hybrid process with incorporation of a forging sequence. The new materials are developed in connection with customers, for example ARMAD® for power transmission and MLX®17, MLX®19 for missiles.

In the reinforcing steels area with high hardness (600HB), substantial progresses have been obtained to get a good ballistic resistance to both great size calibers and numerous impacts. Antoine PROUST, Industeel Research Center engineer at Le Creusot, presented a new steels range heat treated by oil quench under press to get both good flat geometry and structure homogeneity. These steels have a good bending aptitude in substitution to welding connection but when this operation is necessary, it is necessary to use a filler metal of austenitic structure to avoid hydrogen trapping.

Sylvain HENRY, of Constellium Research Center, has presented the new developments of aluminum alloys for Defense Industry. The Al-Li alloys of 3rd and 4th generation are used for structural parts, military bridges and armor plates. In this last area, two grades have been developed, 7056 alloy for resistance to high performance projectiles and 2139 alloy for

resistance to impact of fragments, with a FSW welding which ensures a gain of mechanical characteristics compared to MIG welding. In the field of military bridges, grades 7019 and 7020 provide good stress corrosion resistance with proper heat treatment. The additive manufacturing of aluminum alloy parts is much less advanced than for titanium alloy parts. This activity starts with wire melting technology on parts targeted to customers.

Guillaume RÜCKERT, of Naval Group, presented the issues and perspectives of additive manufacturing in the field of submarines, surface vessels, marine renewable energies that require the assembly of many components of complex shape with long lead times. Naval Group's approach consisted in identifying the relevant parts, lifting the technological locks, developing adapted processes : wire deposit for making parts in substitution for foundry, powder-bed melting for small parts with high added value. Two examples have been shown for the wire deposit : propeller blanks and Pelton wheel reconstruction ; for powder-bed melting, influence parameters have been identified, with a perspective of gradual introduction into production.

Christophe PUPIER, of HEF Group, has presented the evolution of the techniques of surface treatments for the parts intended for the Defense Industry, with in particular microtexturation by ultrashort laser pulses, the use of coated powders to ensure coatings characterized by a very fine and homogeneous distribution of the second phase as well as the development of non-hydrogenated carbon layers to reduce friction. Microtexturation makes it possible to modify the wettability of a surface and its energy transfer efficiency on the environment, the projection of metal powders coated on a polymer (Ag on Co for example) facilitates the flow of charges. The use of coated powders opens new perspectives in the additive manufacturing of complex shaped parts and studies are currently being conducted in this field.

Perspectives of evolution of these families of metallic materials : Nicolas CLICHÉ, Ph student at Mines ParisTech for CEA Valduc, presented on an example, the 316 stainless steel with niobium, the possibilities offered by the coupling of the modeling of the phenomena of restoration, recrystallization and grain growth with the correlations between elastoplastic behavior and microstructure, to obtain a cartography of the mechanical characteristics on industrial part whose getting shape has been modeled by finite elements. The influence of the preconditioning temperature before heat treatment has been clearly demonstrated by this approach, in connection with the behavior of niobium carbide precipitates

Mikael PERRUT, of ONERA, has shown that developments in the modeling of intermetallic phase precipitation phenomena in nickel-based superalloys have led to the quantitative prediction of the microstructure of a high-pressure alloy turbine disc obtained by powder metallurgy, with no adjustable parameter. This modeling, calibrated by structures obtained after different cooling rates, is an essential step to predict the mechanical behavior of the disc and its life.

Marjorie CAVARROC, of SAFRAN Research Center, showed the interest of the coupling of the numerical and experimental methods to accelerate the maturation of the material solutions. The design of materials from databases, the modeling of the process (welding, heat treatment, forging) and the behavior of materials, as well as the development of computing power, should allow progress in the robustness of the choice of materials and processes. Moreover, the development of functional tests, for example in the field of power transmission or the realization of thermal barriers, closer and closer to industrial reality, should facilitate the

selection criteria. Finally, the realization of a demonstrator should allow to accumulate an experience often very useful for the feasibility of the product and its implementation.

Evolution of characterization methods : Nicolas AUTHIER, engineer of CEA DAM Valduc, has presented a new method of measuring the penetration depth of a laser weld. In this welding process, the specification of a penetration depth makes it possible to guarantee the resistance to the different mechanical stresses. The injection of the light of a broad-spectrum diode into the welding beam makes it possible to measure the depression of the surface and therefore the depth of penetration with an accuracy of about 10 µm. Tests carried out on titanium alloys, steels, tantalum, show a maximum error of 6% on the measurement of the depth of penetration. Progress has been made in the lightening of the optical interferometry head and the equipment works well for the welding of sheets up to 10 mm thick. This system is being tested for the control of additive manufacturing.

Jérôme MESPOULET, of Thiot Engineering, has presented the means of characterization of the behavior of structures in high pressure and fast dynamic technology, developed in partnership with companies belonging to the field of Defense. Numerous features were presented, 200kdaN dynamic press, Hopkinson bars, 10 to 10^5.sec^{-1} dynamic means, 100 $kGsec^{-1}$ acceleration generators, 1km to 10 $km.sec^{-1}$ launchers, to evaluate dynamic properties of structures or to modify them for specific applications. Examples of applications from ground to space have been given in collaboration with metal alloy producers, defense industry and research organizations

Closing of the technical day: François MUDRY, member of the National Metallurgy Network, has shown in closing the technical meeting that this day is well in the follow-up given to the report of the Academy of Science and Technology of 20 January 2011. In fact, following this report, a metallurgy mission was set up with training and research centers at the national level, which led to the creation of the National Metallurgy Network bringing together academic laboratories, metal producers and technical centers, as well as reflections on training. In addition, the metallurgical processes sector was strengthened in the East of France with the creation of the IRT-M2P and the Metafensch platform, the Ile de France and Rhône Alpes regions were granted specializations in the respective fields of use properties and microstructures. The presentations made during the technical meeting clearly showed the complementarity between the presentations of industry and university centers, in a field where metallurgical challenges regularly arise.

(1) CEM : Cercle d'Etudes des Métaux, Ecole Nationale Supérieure des Mines de Saint Etienne
(2) IHEDN : Institut des Hautes Etudes de la Défense Nationale
(3) DGA : Direction Générale de l'Armement