Recent Trends in Surface Alloying and Laser Alloying

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Abstract

Many surface properties like high corrosion, high wear resistance and, enhanced hardness are highly required for the advance material use and its application. Through the addition of metal or alloy, new material is generated on the substrate with enhanced properties. Now the addition of the metal layer becomes the part of the original surface. A surface alloying method commonly used in industries to further improvement in the surface properties of metals/alloys. In Common practice, surface alloying involved inclusion; use of interstitial and substitutional particles like carbon-nitrogen, chromium, etc. This work is orientated on surface alloying of a substrate of metals and its fundamental scientific aspects. This paper also has an attempt for the surface alloying methods with special emphasis on laser alloying along with some advantages and further research in this area.

Keywords- surface, corrosion, wear, hardness, phase, laser, etc.

1. Introduction

Nowadays surface alloying is a very familiar technique in the area of material science and manufacturing. In many engineering applications, surface properties have a significant impact on the life of metallic workpieces because the functions that need to be performed by the surface are different from the functions to be performed by the bulk of the job piece. In the area of surface alloying so many methods are available nowadays.

These methods are as a pack, gaseous, plasma, ion beam, and salt-bath for ferrous metal. Using effective surface treatment, less expensive grades of alloys can possibly be used for comparable or even improved service life and performance. Carburizing and nitriding are well-known thermochemical surface treatments to improve the fatigue, tribological, and/or anti-corrosion properties of steel workpieces. There are several surface hardening methods available. One method is to introduce carbon or nitrogen in a workpiece. Similar to carburizing and nitriding, chromizing is widely used surface alloying technologies to improve the high-temperature oxidation and corrosion resistance of the workpiece economically. Nowadays many chromizing techniques exits, for example, pack cementation method, molten-salt technique, and vacuum chromizing process. Pack-cementation is only one cheapest process for chromizing.

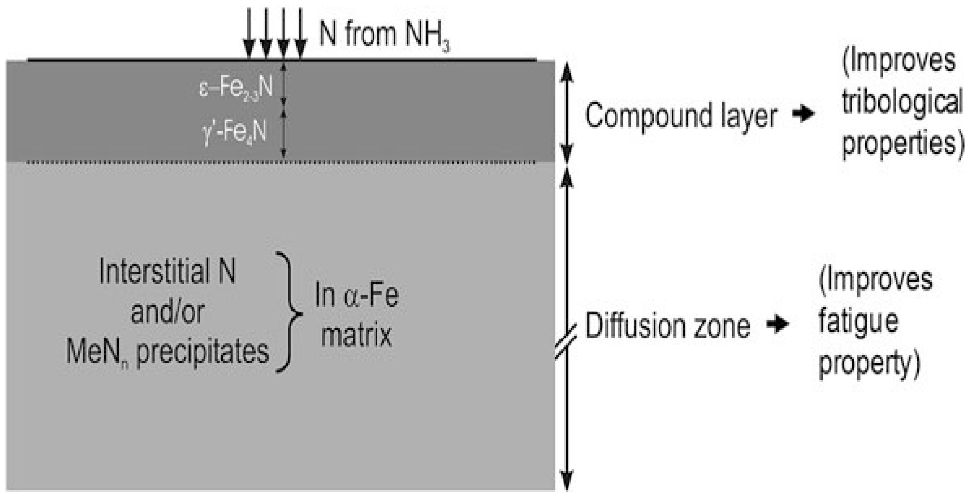

Fig.1 Nitriding operation for iron or iron base alloy [2]

2. Mechanism of surface alloying

In the case of surface alloying there are commonly three steps are involved as a,) absorption b) diffusion c) formation of new compounds. These three steps are as follows

a) Absorption at job surface-
The driving force for this absorption is the difference in chemical potential (or activity) of diffusing species in the surrounding atmosphere (μ_{outer}) and at the surface of the specimen ($\mu_{\text{substrate}}$). At the initial stage, absorption of the diffusing species at the surface is high because the difference between μ outer and μ substrate is high. The maximum surface concentration of the species depends upon surrounding μ. The absorption of species at the surface generates its concentration gradient.
b) *Diffusion*: This causes the transport of species to deeper depths in the cross-section and at the inner surface.
c) *Formation of compounds*: This depends upon the interaction of diffusing species with the elements exits in the substrate.

3. Effect of surface alloying on mechanical properties

There are many mechanical properties that exist in the material and those are further improved by the surface alloying. Some of the mechanical properties like the hardness of substrate, wear-resistance and fatigue property of the specimen or substrate. These improvements in the properties have directly related to the formation of new phases (e.g. compounds of alloying elements). It is also reported that the development of residual stresses/strains in the surface layer during surface-alloying treatment. Further, this stress is of macro and micro levels. Both macro- and micro- stress are responsible for the improvement in fatigue resistance because compressive stress at the surface delays the crack initiation while the latter helps in delaying the crack propagation.

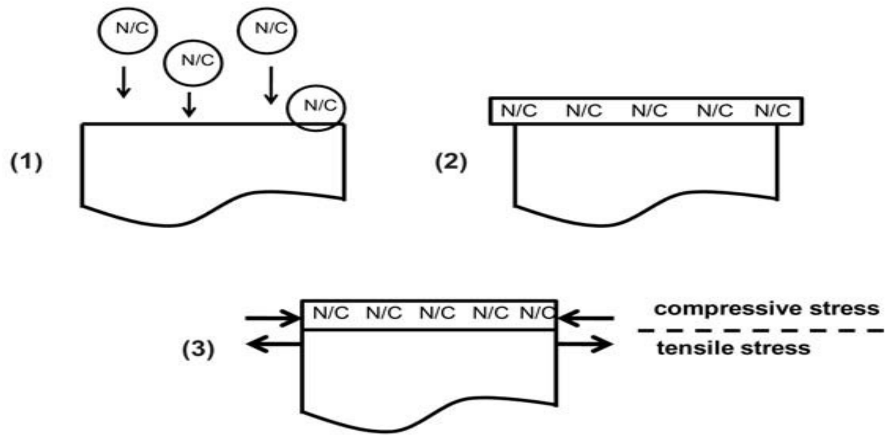

Fig. 2 progress of residual macro- stress/strain at the surface of the specimen during surface alloying. N and C represent nitrogen and carbon, respectively.

4. Surface-Alloying Potential under different condition

The main aim of surface alloying is the alloying under different methods like carburizing potential, nitriding potential, case depth, and diffusion. The ability to carburize/nitriding atmosphere to introduce carbon/nitrogen on the surface of the workpiece, which depends on the chemical potential of carbon/nitrogen in the atmosphere. Under nitriding potential, the Molecular nitrogen is less reactive than ammonia in terms of nitriding of metals. In the nitrogen (N_2) atmosphere, the nitriding potential is proportionate to the partial pressure of N_2 gas. Nitriding of iron using nitrogen gas is impossible because of high pressure (partial) of nitrogen is needed for nitrogen absorption. The covalent bond between N–N atoms is so strong that molecular nitrogen gas will not dissociate into nascent nitrogen at a typical nitriding temperature of about above 500°C.

4.1. Diffusion and Case Depth

The thickness of the surface alloyed layer is an important criterion in designing the components in various applications. Layer thickness depends on the rate of transfer of species, i.e., diffusion phenomena. Diffusion occurs to produce decrement in free energy. There are two widely known mechanisms by which atoms can diffuse through the workpiece: (i) substitutional diffusion (which requires the presence of vacancies) and (ii) interstitial diffusion.

5. A new trend in surface alloying

With the addition of metal or alloy powder, there is a chemical reaction takes place between material and powder particles. After alloying, phase of intermetallic compounds is formed and these phases are required to characterize by hard material. For alloying through the laser the required parameters are power and diameter of a laser beam, scanning speed of laser and powder feeding rate. These parameters should be controlled precisely during the laser operation.

The advantages of material laser alloying include minimal heat input, less impact on material mechanical properties. The laser produces line energy thereby melting the material and powder to deposit. Process parameters play a good role in surface quality and its microstructure. There are direct benefits of laser coating over hard facing, welding, and cladding.

6. Laser alloying

Surface alloying by laser uses a laser source of high density for heating and melting of the required material surface with the inclusion of alloying elements on the melting zone. Alloying by laser is an advanced technology that produces an extremely dense and crack-free structure in developing a good attachment with the parent metal. Laser coating gives rise to new components with high resistant surfaces against wear even at high temperatures or low temperatures. For different applications, laser alloying offers a large range of possible coating materials.

7. Mechanism of Formation of Surface Alloy by Laser

Two main phenomena occur when surface alloying by laser is done which are as thermal transfer and interdiffusion of the different atomic species by mass transport [3]. As both these phenomena are connected, the problem is very complex; indeed the existence of thermal gradients induces diffusion of elements and therefore formation of a new material; physical and thermal properties, thermal conductivity (K), mass density (p), specific heat (c), and melting temperature (MT), progress continuously and frontiers are moving[3]. Since the process requires high skill and operating knowledge for doing the study in this field.

8. Benefits of laser alloying

Some of the direct benefits of laser alloying are as follows

a) The coating can be done for difficult shapes.
b) The lifetime of the specimen is increased.
c) The choice for metal powder for different requirement.
d) Improvement in wear property and less oxidized surface produced.
e) Material life is increased by this method.
f) Increment in tribological properties of the substrate.
g)

Summary

The fatigue, tribological & anti-corrosion properties of less expensive grades of alloys are possible to improve by using surface alloying treatments such as carburization, nitriding process and chromizing. Improvements in the main mechanical features of the substrate surface due to the surface alloying are directly related to the formation of new phases. The main experimental difficulty consists in the determination of available interaction time and energy power density needed to achieve. But in the area of laser alloying when the energy, diameter, and beam speed of scanning are properly adjusted, then the processing gives more attractive results.

References

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