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From Conventional Shot Peening to Severe Shot Peening as a Novel Surface Grain Refinement Method

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Abstract

As a mechanical surface treatment shot peening process is widely used in industry for last five decade. By multiplying the kinetic energy of shot impacts with special combinations of peening parameters is called as Severe Shot Peening (SSP). Recently, SSP processes are also used as a severe plastic deformation method for achieving superior surface properties of peened materials rather than Conventional shot peening. Many type of metallic and ceramic materials may be shot peened. Shot peening affects fatigue properties, corrosion fatigue, stress corrosion cracking, fretting galling and erosion in peened materails. It has been possible to obtain ultrafine and/or nanostructures on or under the surface with SSP.

Keywords

Severe shot peening; Grain refinement; Ultrafine structure; Mechanical surface treatment

Introduction

As metal forming processes, severe plastic deformation (SPD) may be defined very large plastic strain on a bulk material in order to make ultra-fine grains in deformed materials. Conventional metal forming processes, which are widely used in industry such as forging, rolling and extrusion imposed plastic deformation is generally less than about to 2.0. On the other hand, conventional metal forming processes make changing in shape and dimensions considerably. That is why many different type of SPD processes have been developed. Severe plastic deformation methods such as equal channel angular pressing (ECAP), high pressure torsion (HPT), accumulative rollbonding (ARB), constrained groove pressing (CGP), repetitive corrugation and straightening (RCS), cyclic closed-die forging (CCDF), super short multi-pass rolling (SSMR) and torsion extrusion (TE) have been increased in importance due to superior mechanical properties evolution and nanostructured or ultra-fine grains build up. However, inspite of plastic deformation of bulk material, in some cases surface severe plastic deformation methods bring ordinary metallic materials innovations by means of new and effective features. The methods also make contributions on hardness, corrosion and tribological properties. These methods expose plastic deformation with high strain rates to the materials. These superior properties have been achived by mechanical surface treatments.

According to technological aspect, nowadays in some manufacturing cases such as the spring manufacturing, automotive and aerospace industries without mechanical surface treatments can not be completed. In fact the origins of these kind of mechanical surface treatment processes date back to ancient age. However, current applications are to be used widely in military and aerospace technology [1,2].

Shot peening is known as widely used mechanical surface treatment. This mechanical surface treatment process may be defined as peening media produced using different materails with a specific shape and a sufficent hardness that are propelled stream of spherical shots which are accelerated in various kinds of peening devices. These media are interacted with the surface of the treated workpieces. For each piece of shot striking, the material acts as a peening hammer imparting to the peened surface a small indentation. Overlapping indentations develop an even layer of metal residual compresive stress. The maximum compresive residual stress produced at or under the surface layer of a part is at least half of the yield point of the materail being shot peened. In addition, this beneficial effect on the peened materials, surface hardness increases owing to the cold working effect of peening process for many engineering materials. Due to shot peening, they are increase in fatigue properties, corrosion fatigue, stres corrosion cracking, fretting galling and erosion. It is also reported that properly applied shot peening process induces closing of surface open pores for sintered parts manufactured by P/M methods. Some ceramics also shot peened for gaining beneficial effect of peening [3]. The parts to be peened is generally introduced into the shot stream by a mechanical means and is placed to expose predetermined areas of being peened parts. In a shot peening process, there are lots of variables which must be controlled adequately and in a very limited values. Hardness, shape, dimension and material of used shots are very important parameters for choosing proper shot for objective of determined benefits. Shot velocity, air pressure for pneumatic machines, peening time, saturation, coverage Almen intensity are also very important process variables. Velocity and size of shots will determine the depth of the maximum compresive stress. It has to be specify that for proper performance of peened parts shot peening operations should not be completed before reach 100% coverage is achieved.

As it mentioned above, the effect of shot peening has known on the fatigue properties by means of gaining ability to introduce compressive residual stress. Compressive residual stress through the interior retards the fatigue failure of dynamically loaded machine parts. Recently, shot peening with increased shot peening parameters such as Almen intensity, shot diameter and applied air pressure of pneumatic machines has been performed as a surface severe plastic deformation method. Different shot peening parameters are directly related to Almen intensity which covers formation of ultra fine grained layer on the SS Peened parts. Almen intensity is also related to plastic deformation value and directly affects ultra fine crystalline layer thickness and its mechanical properties. In general, the plasticaly

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deformed layer thickness and grain sizes affect the beneficial surface properties after all severe plastic deformation methods. Nevertheless, there is limited number of studies on the Almen intensity effect on plastic deformation, mechanical and physical properties despite being one of the effective parameter of the shot peening process. Some researches showed that hardness close to outmost layer significantly increases by severe shot peening process and the increase on hardness from bulk material to surface is directly related to grain refinement and high dislocation density stratification. It is reasonable that from surface to interior the hardness values decreased due to the reduction effect of plastic deformation, surface hardness variation rather than Almen intensity. Almen intensity and surface hardness are directly related to each other. Hardness of the shot peened surface depends on the rate of severe plastic deformation. However, there is no abrupt fall on the hardness from highly plastic deformed layers to the bulk matrial [4-6].

Ultrafine-crystal structures have become the subject of research in recent years due to their superior mechanical and physical properties and it has been seemed valuable to study ultrafine and/or nano-structured materials. This is because indicative specifications of engineering materials such as abrasion, corrosion and wearing out are directly related to their surface properties and stiffness.

In recent years it has been possible to obtain ultrafine and/or nanostructures on the surface and the regions just below the surface with mechanical surface treatments such as high energy shot peening (HESP), Ultrasonic shot peening (USP) and air blast shot peening (ABSP). In particular, friction and abrasion are substantial characteristics that shall be taken into consideration in application areas. Study of these specifications with the aim to identify the characteristics of the nano crystal materials and develop them in application fields is crucial.

In spite of beneficial effects which are refered above, when SSP process are compared to conventional shot peening, it has a critical disadvantage for surface roughness. Therefore, new application ways such as re-peening and multi step peening have been applied for decreasing surface roughness. For mechanical and physical properties, such as fatigue, fretting fatigue, corrosion, stress corrosion, wear, friction and surface roughness,detailed investigations should be performed for new type of shotpeening processes due to primary importance of surface characteristics [5].

As a results of Severe Shot Peening severe plastic deformation can provide formation of ultrafine and/or nanostructures in very different engineering materials. However, an obtained grain size and a character of an ultrafine and/or nanostructure forming depends on the SSP process parameters applied, processing regimes, phase composition and initial microstructure of a material.

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