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Surface improvement of shafts by the deep ball-burnishing technique

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ABSTRACT

In this article, deep ball-burnishing as a mechanical surface treatment for improving productivity and quality of rotating shafts is presented. When this technique is combined and applied after conventional turning, the resulting process is rapid, simple and cost-effective, directly applicable in lathes and turning centers of production lines.
This process provides good surface finish, high compressive residual stresses, and hardness increment of the surface layer. These characteristics are the key for the fatigue life improvement of the component, and for wear resistance due to the higher hardness.
This work presents a complete analysis of the principal beneficial aspects produced by the application of ball-burnishing. To determinate the influence of each process parameter, several tests were carried out. Once the optimum parameters were established, a complete analysis of the surface characteristics was performed. Surface topographies, sub-surface micro-hardness and residual stresses were measured. Complementary, a finite element model of ball-burnishing was used to understand and predict residual stress values and their variety with the process parameters.
Results show that burnishing is an economical and feasible mechanical treatment for the quality improvement of rotating components, not only in surface roughness but in compressive residual stresses as well.

1. Introduction

Rotating shafts are widely used in important manufacturing sectors, such as automotive, railway or energy industry. Camshafts and railway axles are components commonly designed for lasting up to 30 years of service or even more. Despite this fact, a possible scenario of damage initiation during service due to corrosion, impacts or metallurgical defects could take place. Therefore, fatigue failure is the main cause of fracture in this sort of components. In this way, several authors have studied the relationship between the surface characteristics of parts and their influence on fatigue life [1,2]. The main conclusions were that fatigue life of the component is usually increased by obtaining a good surface finish, high compressive residual stress, and high hardness of the surface layer. Deep ball-burnishing technology permits to obtain these characteristics in turning components.

Mechanical surface treatments have been widely used to improve the physical–mechanical properties of metallic components [3–5]. As a consequence of plastic deformations, compressive residual stress states, work hardening, micro-structural alterations and a favorable roughness are produced; improving fatigue strength and wear resistance [6,7]. Therefore, these surface treatments prevent crack initiation, retard propagation of small cracks, improve corrosion resistance, and even improve wear behavior. Ball-burnishing is a rapid, simple and cost-effective mechanical surface treatment.

The process is based on making small plastic deformations on part surfaces, which cause material displacement from the “peaks or ridges” to the “valleys or depressions” of the surface micro-irregularities. This mechanism is performed by a rolling element that moves over the toolpaths on the surface, applying a regular compression force at the same time. Burnishing systems can be roller-type, in this case the process is known as “rolling” or “roller burnishing”, and ball-type [8,9] whereby the term “ball burnishing” is used. Deep ball-burnishing commonly refers to a hydrostatic burnishing tool capable of supplying pressures of 20–30 MPa, introducing compressive residual stresses over 1 mm in depth. A variation of this technique is the so-called low-plasticity burnishing (LPB) by Golden and Shepard [10]. LPB is a mechanical surface enhancement technology developed and patented at Lambda Technologies. This technique use the minimal amount of plastic deformation needed to create the desired level of compressive stress. LPB is mainly applied to improve the fatigue properties of gas turbine engine components [11,12].

Burnishing improves the surface quality [13–15], increases the surface hardness of the workpiece [16], produces high compressive residual stresses in the workpiece surface [17], and as a result, increases corrosion resistance, wear resistance and fatigue life. Furthermore these improvements are achieved without expensive equipment or long processing times. Thus, ball burnishing can replace

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