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Procedia CIRP 56 (2016) 46 – 49

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9th International Conference on Digital Enterprise Technology - DET 2016 – "Intelligent Manufacturing in the Knowledge Economy Era

Optimization of the Manufacturing Defects of Plunger Unit based on Ion Implantation

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Abstract

Plunger unit is one key component of plunger bump and its manufacture quality decides the performance of plunger bump. In the necking-in process of plunger seat, there always be a large amount of manufacturing defects including violent plastic deformation, manufacturing stress and micro-structure transformation. And when plunger units work normally, these defects may lead to failure even equipment broken coupling with the complicated working condition and other environment factors. To address this issue, the ordinary failure forms of plunger unit are summarized from the factory. Manufacturing stress is chosen as the key factor influencing the reliability of components existing in the surface of the plunger seat. And combining with physics of failure, the relation between manufacturing stress and other defect is discussed. After that, Ion implantation technology is used to change surface structure to optimize manufacturing defects. FEM is used to simulate pull-off force and residual stress. Friction and wear test is carried out to measure the variation of friction coefficient. Finally, reliability of plunger units is improved by comparing performance parameters.

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production

Keywords: manufacturing defects; plunger unit; ion implantation; FEM;

1. Introduction

Plunger pump is extensively applied in aerial products and mechanical equipment for its delicate structure, high stress pressure and high efficiency [1]. Performance of plunger pump is decided by the quality of plunger units and good quality of necking-in technology plays an importance influence on good performance, long service life and high reliability. Plunger unit is made up of plunger seat and plunger. It is shown in Fig. 1. The necking-in process is one process that the metal of plunger seat is squeezed to wrap plunger ball with plastic deformation. After that, sphere surface can make the roll loose to guarantee fixed clearance and other technical indexes. In present manufacturing situation, necking-in process is not mature enough to produce plunger units with high reliability, stable performance and high quality.

When plunger bumps work normally, its main shaft brings rotor to move. And there is angle of inclination in slant plate, the plunger will circle motion and back-and-forth movement to change the volume of plunger to draw in oil and discharge oil [2]. Because the plunger unit is the motivation part, its failure usually lead to the failure of plunger bump. The structure of plunger unit is shown in Fig. 1.

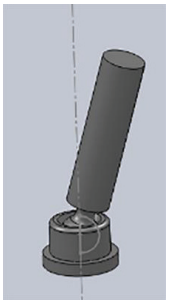

Fig. 1 The structure of plunger units

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doi:10.1016/j.procir.2016.10.014

Based on knowledge of necking-in technology, there is a large amount of processing defects occurring on the surface of forming position. The defects include micro-structure, machining surface layer and residual stress and these defects leading to failure of components. And many scholars have studied the failure of plunger units. Jinxian Duan [3] discussed the problem of long falling off time and long shut-in time in oil production and fluid expulsion and gas recovery by using conventional plungers. The research introduced one new shape and key technical points which would influence the velocity of process. Hongping Yang [4] made introduction about the recent plunger assembly shut technologies, pointed out the advantage of different technologies and proposed assume of the improvement of plunger units. Zhipeng Zhang [5] discussed the relation of wear-out failure between plunger root and plunger units. Changying Zhang [2] made the analysis of early failure in the plunger units and optimized the structure of plunger unit, improved the process technology and improved the machining precision. Finally, the rate of early failure decreased a lot.

The main reason of the failure is that manufacturing defects are not paid enough attention. Manufacturing defects especially manufacturing stress will play a big influence on the performance of mechanical components. And it usually leads to failure of plunger unit such as components deformation, even the destruction of plunger seat with hard working environment. It is necessary to optimize the stress and other defects existing in the surface of plunger seat.

Zhangyi Zhou [6] studied effect of welding residual stresses on the fatigue behavior of steel structure, discussed the industry principle and adopted some methods to reduce the stress. Xiaohui Jiang [7] made investigation on the mechanical of the residual stress and discussed control method of mechanical accuracy for the complex thin-walled parts. Zhitao Tang [8] discussed residual stress and deformation of aerospace aluminum alloy in machining. With development of surface finish technology, there are many advanced techniques improving the state of manufacturing stress.

2. Optimization Method of manufacturing stress

2.1. Procedure of machining and manufacturing stress

The structure of plunger unit is accurate and machining processes of plunger units includes rod processing, surface heat treatment, half necking-in, rolling loose and assemble, first running-in, dismantling detection and second running-in is complex. The main process flow is shown in Fig. 2. Necking-in process of plunger unit is a delicate technology which helps plunger seat work normally with plunger ball [4]. Half necking-in technology is one typical process including two kinds according to difference of ball loose. One kind of half necking-in technology includes six levels that each one is smaller than the next one from first level to six level. Oil press machine pass the product to six-level mold to get the external plunger ball wrapped by plunger seat to finish necking.

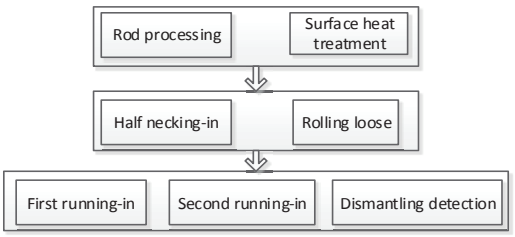

Fig. 2. The main process flow of plunger units' machining

It is inevitable that almost all machining procedures would produce deformation to the surface of product. Some of deformation would cause manufacturing stress. In general, manufacturing stress was often classified into two different types including compressible stress and tensile stress [5].

Compressible stress is caused by in-homogeneous deformation. Its nature is the lattice distortion and extra energy. And compressible stress can improve the fatigue strength, ultimate tensile yield and stable design. In actual engineering, compressible stress sometimes IS introduced to mechanical products to improve their performance.

In the contrast, tensile stress is harmful to product. When there is tensile stress in material, ultimate tensile strength will decrease original value and its deformation will be unstable. When product works in actual environment, tensile stress may accelerate the failure with external stress. Therefore, tensile stress of products is eliminated to avoid negative influence caused by it.

From the Fig. 2, there are many different kinds of machining technologies producing deformation. The failure analysis of broken plunger seat was made to get the most important position where may exist a large amount of deformation and stress. And then, ion implantation was adopted to optimize the surface state and distribution of manufacturing stress.

2.2. Ways of eliminating manufacturing stress

Manufacturing stress exists in mechanical products in the unstable state. During actual use, manufacturing stress was the defect and it need to be released in some ways to avoid cause serious accident [10].The goal of eliminating residual stress can be achieved by two ways in nature. One method is that enough energy is given to metal atoms to help them go back to equilibrium position [11]. The other one is that the part was made to produce some plastic yield. At present, there are some technologies in solving manufacturing stress.

Natural aging is one method to leave casting components static a long time to decrease stress. But the effect of natural aging is finite. Heat aging is one method to heat mechanical components to be the plastic state with the range of special temperature. Its theory is the thermal relaxation and this method is relatively mature and reliable. Vibration stress relief is one method to use the vibration generated by other ways to loose or reduce the actual residual stress. It develops quickly because it takes less investment and less energy. Shot blasting is an effective way to strengthen mechanical