Advanced Materials Research *Online: 2009-05-05*
ISSN: 1662-8985, Vols. 69-70, pp 6-10
doi:10.4028/www.scientific.net/AMR.69-70.6

Dynamic Numerical Simulation of Mould Free-form Curved Surface Gasbag Polishing

S.M.Ji[1, a], L.Zhang[1, b], M.S.Jin[1, c], Q.L.Yuan[1, d] and Y.Q.Shen[1, e]

[1]The MOE Key Laboratory of Mechanical Manufacture and Automation, Zhejiang University of Technology, Hangzhou,China ,310032

[a]jishiming@zjut.edu.cn; [b]zhangli@zjut.edu.cn, [c]jms611@163.com, [d]yuanql@zjut.edu.cn; [e]qiqishen@163.com

Keywords: Dynamic numerical simulation, Gasbag polishing, Polishing technologic, Mould

Abstract. Polishing is an important technics processing in order to obtain the high quality surface of mould in industry mould manufacture. For the moment, polishing of the free-form curved surfaces of mould is performed by manpower. So it is important to research gasbag polishing technology. This paper has been developed dynamic numerical simulation for gasbag polishing process based on the new type of polishing tools by FEM. On the material removal theory, influence of the shape of the structure of the gasbag, angular velocity and the air pressure inside the air gasbag on the campaign polishing process are explored. It can be used to provide technology support to establish polishing process database.

Introduction

Gasbag polishing technique is a new superprecise polishing method which is proposed by the London Optical Laboratory in the nineties of the twenty century. In 2000, the London Optical Laboratory and the Zeeko Company worked together to develop the IRP series polishing machine tool, it is used to aspheric surface and free-form curved surface [1,2]. Now the Zeeko Company has already developed the IRP-1000 polishing machine tool whose maximum diameter of the workpiece is 1000mm. Its surface accuracy reaches 80nm PV, and its surface roughness reaches 3nm.

Moulds are widely used. Among them, 65% of the die spaces have curved surfaces, and 40% of them have free-form curved surfaces. It will take 50% of the time for surface polishing. For the moment, polishing of the free-form curved surfaces of mould is performed by manpower, which has very low productivity effect and unstable polishing quality. So it prevents the development of mould industry of our country, many superprecise moulds are import.

So, it has great signification to mould industry by using gasbag polishing technology and studying highly efficient, precision and automated technology of free-form curved mould.

Many researchers have explored a large number of methods for improving curved surface polishing quality and efficiency and implementing polishing automatism. Mooney-Rivlin constitutive model is adopted to describe the mechanics behavior of rubber material [3, 4]. The contact force on the mould surface is simulated based on the software of ANSYS. The theory analysis on distribution and strength of stress in the contact area can be validated by the simulative result, and the material removal model is established on the basis of other researchers' contribution to the study of material removal [5-7].

But the research about the polishing of free-form curved mould is very seldom. In this paper, based on the material removal theory of gasbag polishing, by using FEM software, the stress distribution map and the time-travel curve of the appointed cells of contact area are obtained. By comparing the appointed cells' physical characteristics in different parameters, including the structure, palstance of the gasbag, the air pressure inside of the gasbag, the infection caused by technics parameters to gasbag polishing are studied. It can provide technology support to establish polishing process database.

Model analysis

Material removal model. The Classical Hertz contacting theory and material removal Preston equation provide basis for calculating the stress distribution in polishing contract area and constructing the material removal model of gasbag polishing [8-10].

In the polishing process, local material removal rate dh/dt on the certain polishing area has been expressed as follows by Preston equation:

$$dh/dt = K \times P \times V \tag{1}$$

Here, dh/dt is determined by the Preston coefficient K, the polishing pressure also called contact stress P and the relative velocity V between polishing tool and mould surface. K is related to the materials of polishing tool and mould, granularity of abrasive powders, and other factors such as the influence of different material removal mechanisms, the chemical action, and so on.

Building up the FEM model. Main parts of the gasbag polishing model are the workpiece, the flexible gasbag and the rigid body. Among them, model of the workpiece is a cuboid. Model of the flexible gasbag is an hemisphere hull. Model of the rigid body is column ring. The model at last founded is shown in Fig.1.

The decrement, the palstance and the air pressure expressed of the gasbag are expressed as n, w and P. When $n = 0.001(m)$, $w = 140(rad/s)$ and $P = 25000(Pa)$, choose several time points of the polishing process, the equivalent effective stress distribution of the workpiece surface is shown in Fig.2.

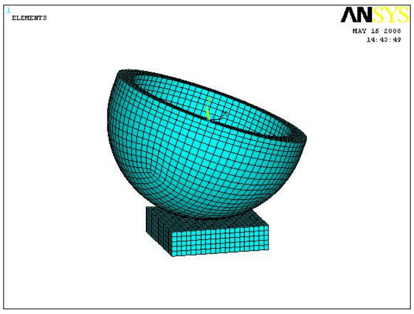

Fig.1 FEM model of the gasbag polishing tool

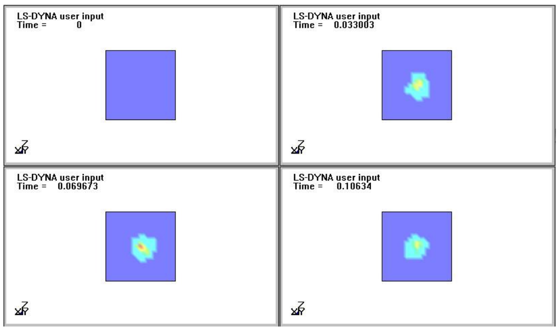

Fig.2 Equivalent effective stress distribution of the workpiece surface

From Fig.2, the contact area of polishing surface recedes into the stress from the center to the external part. Thus, surface of the workpiece can be divided into three parts according to stress, the largest stress part, the transition part and the edge part. Choose one point of each part, marked with 1091, 1093, and 1095. Those points are analyzed with FEM.

Dynamic numerical simulation gasbag polishing process

According to the material removal theory of gasbag polishing, the material removal rate is related with the pressure between gasbag and workpiece, relative velocity of gasbag and worlpiece and the coefficient K_p. And these three factors are related with the decrement, palstance and the air pressure expressed of the gasbag. When simulating, three representative points in the contact area are selected. By dealing with the equivalent effective stress-time curve of these three points under different technics parameters, the average equivalent effective stress is obtained. By comparing average equivalent effective stresses under different technics parameters, combining with the material removal theory of gasbag polishing, the influence caused by technics parameter to material removal rate is studied.

Influence caused by decrement to material removal rate. When the technics parameters values are shown in table 1, the equivalent effective stress-time curve of three models are shown in Fig.3.

Table 1 Technics parameters values

Group	Compression deflection n(m)	Palstance w(rad/s)	Air pressure P(Pa)
1	0.0005	157.5	25000
2	0.001	157.5	25000
3	0.0015	157.5	25000

According to Fig.3, when the palstance and the air pressure have the same value, along with the increasing of the decrement, the average equivalent effective stress of No.1091, No.1093 and No.1095 models are increasing too. So we can say that in the whole polishing area, the average equivalent effective stress of every model is increasing with decrement. In the other hand, along with the increasing of decrement, the contact area is increasing too. So in the whole polishing area, the contact area is increasing with the decrement. According to the material removal theory, the Preston coefficient K_p is increasing with decrement, in the same time, material removal rate is increasing too according to Preston equation.

Influence caused by palstance to material removal rate. Take the values shown in Table. 2, the equivalent effective stress-time curves of No.1091, No.1093 and No.1095 models are shown in Fig.4.

Table.2 Technics parameters values

Group	Compression deflection n(m)	Palstance w(rad/s)	Air pressure P(Pa)
1	0.001	70	25000
2	0.001	104	25000
3	0.001	157.5	25000

According to Fig.4, while $n = 0.001(m)$ and $P = 25000(Pa)$, the average equivalent effective stress of No.1091 model is first increasing and then decreasing along with the increasing of palstance. And the changing of No.1093 and No.1095 models are not so obvious. As the decrement is unaltered, the contact area between gasbag and workpiece surface is unchanged too. Thus as the increasing of palstance, the pressure made by gasbag to workpiece did not change significantly. Besides, along with the increasing of palstance, the relative velocity of gasbag and workpiece is increasing too. According to the material removal theory of gasbag polishing, the Preston coefficient K_p is increasing with palstance. And the gasbag pressure did not change significantly, when the relative velocity of gasbag and workpiece increases, according to the Preston equation, the material removal rate increases.

Influence caused by air pressure to material removal rate. Take the values shown in Table. 3, the equivalent effective stress-time curves of No.1091, No.1093 and No.1095 models are shown in Fig.5.

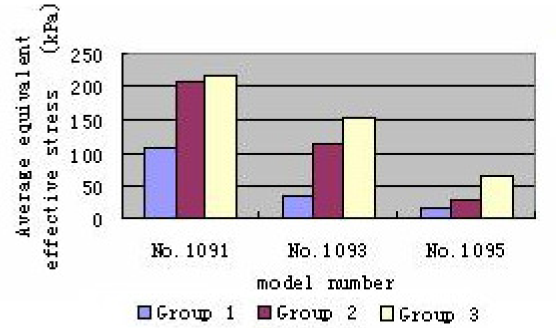

Fig.3 Influence caused by decrement to material removal rate

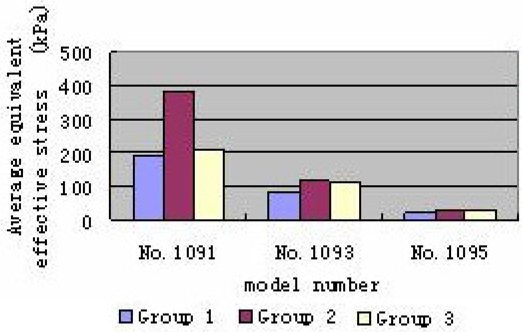

Fig.4 Influence caused by palstance to material removal rate

Table.3 technics parameters values

Group	Compression deflection n(m)	Palstance w(rad/s)	Air pressure P(Pa)
19	0.001	157.5	0
20	0.001	157.5	12500

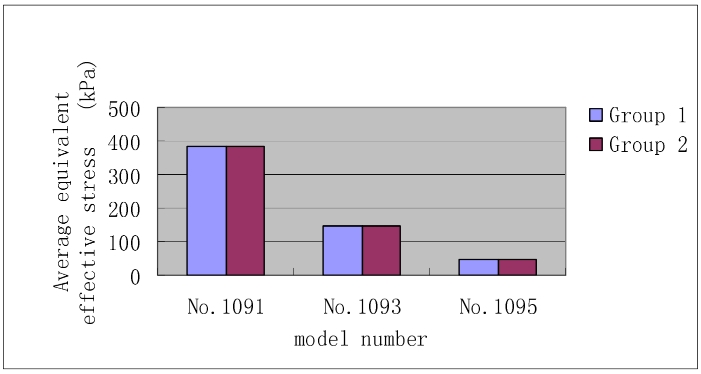

Fig.5 Influence caused by air pressure to material removal rate

According to Fig.5, while $n = 0.001(m)$ and $w = 157.5(rad/s)$, the change of average equivalent effective stresses of No.1091, No.1093 and No.1095 models unobvious. It can be concluded that the average equivalent effective stress in contact area is almost keep the same. As the decrement is unaltered, the contact area between gasbag and workpiece surface is unchanged too. Thus As the increasing of air pressure, the pressure made by gasbag to workpiece did not change significantly. According to material removal theory, along with the increasing of air pressure, the Preston coefficient K_p is increasing too. According to the Preston equation, the material removal rate increases.

Conclusions

Based on the simulation result and the material removal theory, the influence caused by decrement, palstance and air pressure of gasbag to surface roughness are included as follows.

(1) With the increasing of gasbag's decrement, the pressure caused by gasbag to workpiece increases too, meanwhile, hold facility of the gasbag to abrasive particles increases, depth of surface nicks caused by abrasive particles to workpiece increases at the same time. As the surface nicks gets more obvious, surface roughness get worse.

(2) The influence caused by palstance to surface roughness. The relatively linear velocity in the contact area increases with the palstance. The expediting of the polishing solution's circle velocity

leads aggrandizement of the fluid pressure in polishing contact area. And the depth of surface nicks caused by abrasive particles to workpiece increases at the same time. As the material removal gets enhanced, surface roughness gets worse.

(3) With the increasing of the air pressure in the gasbag increases, the pressure caused by gasbag to workpiece did not change significantly. Thus, with the air pressure in the gasbag increases, the pressure caused by gasbag to abrasive particles did not change significantly, and the surface nicks are not obvious, the surface roughness changes not much.

Acknowledgements

This paper is supported by National Natural Science Foundation of China (NO. 50575208) and Zhejiang Province Natural Science Foundation (NO. M503099).

References

[1] K.Saito,T.Miyoshi,T.Sasaki:CIRP Annals-Manufacturing Technology,Vol.42(1993),pp.553-556.
[2] D.D.Walker et al: Proc. SPIE,Vol.4451 (2001), pp.267-276.
[3] X.Yang:*Finite element method of nonlinear rubber material* (Petroleum Industry Press, Beijing, 1999).
[4] M.J.Zheng,W.J.Wang,Z.N.Chen:Vol.50(2003),pp.462-465.
[5] C.Wang,S.C.Lin,H.Hochen: Int. J. Mach. Tools Manuf.,Vol.42 (2002),pp.979-984.
[6] B.Ekkard,R.Oltmann,G.Alexander: Precision Engineering,Vol.30 (2006),pp.325-336.
[7] M.Y.Yang,H.C.Lee: J. Mater. Process. Technol.,Vol.116(2001), pp.298-304.
[8] F.W.Preston: J Soc Glass Technol,Vol.11(1927),pp.214-56.
[9] K.L.Johnson:*Contact Mechanics*, 1st ed. (Cambridge University Press, England, 1985).
[10] A.C.Fischer-Cripps:*Introduction to Contact Mechanics*, 2nd ed. (Springer Science&Business Media, 2007).