Mechanism and Technical Research of the Magnetic Abrasive Finishing in Freeform Surface of Die&Mould

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Abstract: To solve the problem of free curved surface finishing at present. According to the requirement of curved surface of the mould polishing, combining the theory of electric magnetic field, adopting the magnetic abrasive, accomplishing the mould free curved surface polishing with magnetic power. Bring forward the new craft of polishing process among magnetic field. The processing characteristic of the magnetic power is set about, the main parameter of the polishing craft course are analyzed, and carry on discussion to make out and produce the orbit of magnetic abrasive grind movement, put forward the process method of obtaining even freeform surface removal through magnetic abrasive polishing.

Introduction

At present, the shape of the mould is becoming more complicated, the proportion of freely curved surface is increasing constantly, high requirement of process technology for mould to be put forward to guarantee high manufacture precision, surface quality and the esthetic surface. As application of numerical control, Electrical Discharge Machining and CAD/CAM system, and automation can be basically realized to polishing the curved surface of mould. But at present the process of polishing of mould, mainly rely on the experienced operator. The polishing time take $30 \sim 50$ percent of the whole time, it become the bottleneck of manufacture of mould. It means the proficient worker is indispensable, at the same time the process is time-consuming and strenuous, the stability of quality of surface after polishing is difficult to guarantee too. Especially at the last stage of polishing, if something is wrong it may cause the scrap of the whole mould, thus may cause very great economic losses.

The freeform surface is a complicated, irregular, non-rotating surface, and generally it is very difficult to describe accurately with the mathematics equation, mechanical movement principle, etc. As the magnetic power polishing is advantages, such as very good flexibility, self-adaptability controllability, etc. so it can make the work piece surface of complicated form with lower roughness, According to characteristic in magnetic abrasive finishing of the mould in this paper, analyze the main parameter that affect magnetic abrasive polishing and the orbit of magnetic abrasive polishing, probe into the method of getting even surface removal amount in magnetic abrasive finishing of the mould.

The mechanism and characteristic of magnetic abrasive finishing. The method of magnetic abrasive finishing is adopt with magnetic abrasive, through the function of the magnetic power in the magnetic field, the magnetic abrasive (can be attracted by the magnet and grinded into powder which is used to polish the work piece) is kept on the work piece surface, and keep certain interval between work piece surface and magnetic pole. So magnetic particle is arranged in an orderly manner along the magnetic power line in the interval of manufacture, and form a magnetism brush, enclose on the work piece surface under the magnetic power. As the magnetic field or the work piece rotate that make a relative motion between magnetic brush and work piece surface, will polish the work piece surface with magnetic abrasive. Often use some apparatus such as the numerical control milling machine or machining center while polishing. The basic method is as shown in Fig. 1[1, 5].

The characteristic of the magnetic abrasive finishing is: (1) The grinding particle make up the brush magnetically in the processing interval, changing as profile surface of work piece change, enclose, roll, separate in the surface profile modeling of the work piece, is not restricted by surface form; (2) Because keep certain interval between work piece surface and magnetic pole, have a very good processing flexibility, can carry on polishing treatment to the surface of the arbitrary profile. (3) Because magnetic power line can penetrate object like X ray, so magnetic particle can enter arbitrary inner surface of profile that ordinary cutter can't get involved, for instance mould cavity, inside some bend cannular, small bottleneck container, etc.: (4) Through change external magnet change the direction of magnetic power line, can control magnetic abrasive finishing according to fixed orbit surface, finishing the field that be unable to be processed at past time [1].
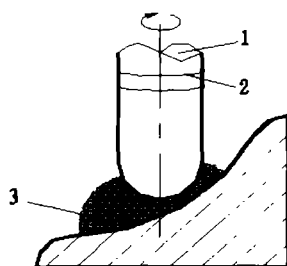
1.   Magnetic pole of the tool   2、Magnetic power coil   3、Magnetic abrasive
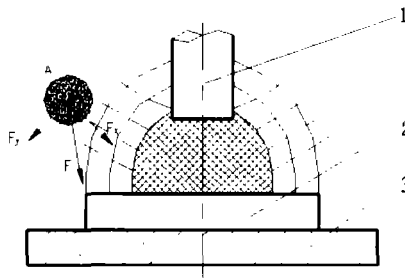Fig 1 The Sketch Map of Magnetic Abrasive Finishing on Die&Mould
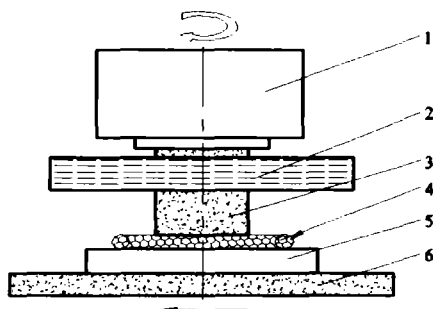
1. NC Milling machine 2.Coil 3.Core 4.Magnetic abrasive 5.Work Piece 6.Working Bench
Fig 2 The Sketch Map of Magnetic Abrasive Finishing

Analyze the mechanism and course of magnetic abrasive finishing.

The magnetic abrasive finishing of curved surface. The device of polishing curved surface is usually made up of three parts, the tool as magnetic pole, magnetic abrasive and magnetic power coil. The magnetic abrasive is under the attraction of the electric magnetic head, arrange in the shape of brush according to the form of the magnetic field. Have flexibility because of such polishing tool, can keep in touch with the curved surface better, relatively suitable for the curved surface polishing. The magnetic head is mostly used in curved surface polishing like Fig. 2, the magnetic head is a sphere, and the work piece is a free curved surface [1, 2]. Keep the coil of magnetic pole and lathe center of gyration in this method, magnetic pole bottom and work piece leave certain interval (usually 1~3mm), this interval, mainly in order to pack the magnetic

abrasive between polishing tool and work piece. Even if the work piece surface has a lot of concave and convex faces, the magnetic abrasive can change with change like it. Even if surface of work piece is complicated freeform surface, control lathe own sport orbit of a certain degree, can also make complicated freeform surface make getting better polishing result, some ordinary grinding method can't process obtain thinner roughness of surface [2,5].

Analysis magnetic power. According to the principle of Magnetic Abrasive Finishing, putting the magnetic abrasive into magnetic field, magnetic abrasive being arranged along direction of magnetic power line into " the magnetic power brush " in an orderly manner among magnetic field. Putting the work piece in the middle of N, S of the magnetic pole, keep work piece some distance between S and N, making a relative motion between magnetic pole and work piece, magnetic abrasive finishing will be processed on surface work piece as Fig 3. The particle A in the magnetic power, it receives two strength, one is strength F_x on the line of the same magnetic location; another one is the magnetic power F_y on the line; the two strength merge magnetic power F_0. Because of magnetic power F_0, magnetic abrasive centralized in magnetic field, prevent the particle from spreading outwards because of centrifugal function when magnetic pole rotate, meanwhile, exert pressure to the work piece surface. In the magnetic field, the magnetic abrasive receives magnetic field power F:

1. Magnetic 2.Work Piece 3. Working Bench
Fig 3 The Sketch Map of power analysis of
Magnetic Abrasive Finishing

linear   sine curve   pendulum line

epicycloids   hypocycloid   ellipse
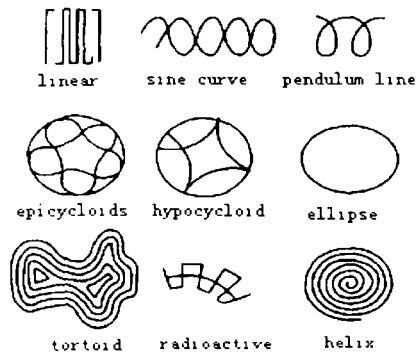
tortoid   radioactive   helix

Fig 4 the commonly movement trajectory
diagram of magnetic abrasive finishing

Analysis the mechanism of magnetic abrasive finishing. The magnetic abrasive finishing is nearly same with other ways of mechanical polishes essentially, The mathematical model of the optics polishing craft can be description according to the Preston empirical formula, the relative pressure of the common machinery polishes between the flexibility rubs and the work piece, but magnetic abrasive finishing is the magnetic power or the magnetic field strength. Namely:

$$R (x, y) = K P (x, y)V (x, y) \tag{1}$$

R (x, y) is removal of the material in unit time of the point power in the contacts region of magnetism rubs and the work piece, the P (x, y) is magnetism rubs produce a magnetic power on the work piece, V (x, y) is the relative motion speed between the work piece and magnetic pole, K is a related proportionality constant with the processing condition.

May see from the above formula, the mold surface and the magnetic abrasive contact region produce the surface removal have close relationship with this intensity of distribution of magnetic pressure area. At the time of the polishing tool polishes to the mold freeform curved

surface, the direction of polishing power usually along the freeform curved surface normal direction, under the function, between the magnetism brushed and the mold surface forms a magnetic power area, the mold surface material is removed in the magnetic power area.

Considered the above analysis, supposition maintenance magnetism rubs a regular rotational speed, enters a certain speed, processed the mold surface to select any A (x, y), magnetism rubs grind A (x, y) keeps the definite time, the quantity of removal of A (x, y) to be decided mainly by the polishing tool's pressure variation. Using mathematics double integral equation, the expression of removal of molds surface A (x, y). $\triangle$ R is showed in Eq.2.

$$\Delta R = K \iint_{\phi} P(x-u, y-v)R(u, v)dudv \tag{2}$$

$$\Delta W = KP(x, y) \iint_{\phi} R(u, v)dudv = K'P(x, y) \tag{3}$$

In the formula, R (u, v) the distributed characteristic function is under the unit pressure in the mold zone of contact the material removal; P (x-u, y-v) is the pressure variation function when polishes, ϕ is the region way for polishes. Supposes polishes region relative work piece size unusual small, uses the pressure control model, then may think: Polishing tool contact action A (x, y) the region is very small, the pressure approximately equal A (x, y), namelyEq.3.

May see from the Eq. 3, if uses the steady magnetic power model, the polishes removal is decided by magnetic power the magnetic tool action in this section. Therefore determines the value of magnetic field pressure, makes the smooth modeling again of the entire curved surface pressure, can control the value of polish removal.

The influence parameter of magnetic abrasive finishing. The influence of processing efficiency and the quality factor of magnetic abrasive finishing is so many, such as the magnetic power size, the rotational speed of grinds and enters the processing of material quality, the process time and so on, and the magnetic power mainly decide by the magnetic field strength, the change rate of magnetic field strength, the magnetic abrasive diameter size, the magnetic abrasive magnetic susceptibility. Here introduces several essential factors here [5].

Magnetic abrasive. In the magnetic abrasive finishing, the magnetic abrasive is the extremely essential factor, its size directly influence the processing quality, stability and efficiency of work piece, therefore magnetic abrasive preparation craft deeply valued by domestic and foreign experts. Indicated by the multitudinous experiment that increases the particle size, magnetism attraction the sharp growth, skids between the granule can reduce relatively, the magnetic power brush constitutes by the magnetic abrasive to can better follow to pole rotates, the skids relatively between the granule also reduces. But, the processing space is limited; Moreover, with particle size increasing, the cutting edge quantity participates in cutting reducing at the same time, causes to the efficiency of polishing to reduce; In other words, the particle size has a best value.

The intensity of magnetic field. Regarding non-magnetic material work piece, on the one hand we may change the arrangement condition of magnetic power line through changing magnetic pole the direction, thus achieved the goal of enhancement the working efficiency of polishing; On the other hand, change the rate of magnetic field strength is also not allow to be neglected, may obtain it through the change magnetic pole shape. It affects the magnetic field distribution, moreover, affects the direction magnetic power line too, and affects the stressful condition of magnetism abrasive grit in the magnetic field. Usually uses the way cutting a slot in the magnetic pole gains the magnetic field strength rate of change. Because after slot in magnetic pole, it make work interval different, obtains the magnetic field strength was also different, has strong and the weak change of the magnetic field. The magnetic granule always flows to the magnetic power big place, it promoted the fluidity of abrasive, and large scale enhances the efficiency of magnetic abrasive finishing.

Interval of work. The size of magnetic field strength is related with work interval, namely, has the inverse ratio with the distance between the magnetic pole N and S. When the work piece is the magnetic material. The work piece is magnetized in the magnetic field, becomes the new magnetic pole, the work piece and the magnetic pole gap is the work interval, this interval usually is very small in this time, about 1~3mm, may obtain the big magnetic field strength, the efficiency of polishes will be enlarged. So it can be seen, work interval smaller, magnetic power bigger, the efficiency polishes also higher. Regarding the complex shape mold, may change the shape of magnetic pole, the components surface shape as far as possible to match the shape of magnetic pole, reduces the work interval as maximum limit, thus enhances the efficiency and the processing quality of polishes.

It has a best work interval scope of each kind of material, May obtain the small Ra value in this scope, Oversized or the small work interval will cause the Ra value to increase. When the work interval smaller, the magnetism line is short, the flexibility of "the magnetic power brushes" reduces, Scratches seriously the surface, causes the Ra value to increase. When processing interval oversized, the magnetic resistance enlarge, the magnetic induction intensity is weaken, and the pressure to grinds reduce, the efficiency to reduce. When thickly grinds the gap value chooses small general, and the precision polishes, the gap value chooses big somewhat. Through programming when selects the remainder to guarantee the work interval. But regarding the different curvature and the different slope angle of mold-curved surface, because the magnetic power line has uneven phenomenon, the slope angle is bigger, the radius of curvature is smaller, the polishing became smaller. In the actual finishing quantity have the difference, uses the short fiber magnetic polishing compound to polish the free curved surface is good solution at present. Moreover the discrimination judgment to the different slope angle of mold curved surface is adopted, Adopts different path polishing to solve the question of non-uniformity gap between the object and the tool magnetic pole.

Relative influence between magnetic pole and work piece motion speed. In normal working condition, the work piece relative magnetic pole movement fast goes past quickly, grinding length of the unit time increase; the material removal to be bigger, The Ra value correspondingly reduces quickly. But the relative speed between the work piece and the magnetic pole is as big as the certain degree, The abrasive grit can be departed along the work piece rotation tangent bearing, Causes the stability of processing to be blocked, When it is serious, all grit in work interval can depart cause the ability of polishes to loses. It has divided into many factors to bring the certain influence to the processing, as magnetic pole shape, processing material quality, processing factor and so on.

The polishes path of magnetic abrasive finishing. Manually polishes and the machine usually are used in the mold curved surface polishes process, but no matter operator's how to process, he always uses the polishing tool by a certain posture processes on the mold surface, and along polishes the path to process the mold surface. The magnetic abrasive finishing as one kind of machine polish, must cause to production of the path polish to achieve the ideal effect, Not only request to compute speed quick, and take a few of the computer memory, Moreover it must cause to cut the good spacing that even distribution, the processing error small and consistent too, the reasonable length of feeds and the processing higher efficiency. Therefore polishes path to have to guarantee the work piece surface processing and the tool magnetic pole surface has the same or close condition of cut. The tool magnetic pole movement also should guarantee each spot on the work piece has the same or closely journey of polishes, and as far as possible to avoid the periodic redundant situation. At the same time do every effort to make polishes the movement steadily, Avoids the oversized curvature angle as far as possible [5]. The convention polishes path mainly is: the linear, the sine curve, the inferior cycloid, the outside cycloid, the hypocycloid, the ellipse line and so on [4,5]. But regarding the overwhelming majority mold curved surface, especially the path of the mold cavity curved surface polishes is more complex. Uses for polishing the path to produce are usually mainly has the projection, the

same parameter line processing method and so on.

Computational method of projection processing. The projection processing method is applied extensively; this is the easy method to produce the path. Establishing the path first, then projects this path to in the curved surface of the mold, which the image plane will polish. There are many paths of magnetic abrasive finishing, not all of path suit the curved surface polishing, as the outside cycloid, the hypocycloid and so on. It has been used mainly such as the straight-line type, tortoid, the emission linear and the spiral linear. It is not easy to duplicate the sine curve, inferior cycloid, ellipse line path in polishing, it's advantageous to reduces the surface roughness, but the path production has difficulty and must adopt the certain programming method to produce, producing plane curve path, then projecting it to the mold surface use the method of curve drive, to obtain the good result, as Fig 2 shows [5].

The computational method of the same parameter processing. Because the curved surface of mold usually has the massive surfaces, is not composite by the sole curved surface, and therefore uses merely the same parameter line processing method is difficulty. Therefore sometimes use more the same parameter processing method. The goal is, a parameter line of tool cuts along the curved surface (u direction); another parameter line (v direction) is the row spacing direction, it is easy to control the curved surface, the different partial curvature of curved surface adopts the different row spacing to control the superficial roughness.

Usually needs to adopt the method of the reconstruction of curved surface to establish mold many curved surface as a quite close actual curved surface, according it to produce actuation curved surface, then projects it to the actual mold curved surface to polish. At the same time we must consider angle change of the different region, when produce path must consider divisive the steep region and the gentle region, through adopts the different processing gap and the movement way to solve this problem.

Conclusions

The polishing is the important working procedure to improve the mold quality. To compare with other technology, because the cutting tool is elastic abrasive magnetism brushes, The abrasive contact the work piece is even, the ability of attracting vibration is better, and guarantee surface original geometry precision and the shape precision cannot be destructed, and make it to manifest the extremely obvious superiority to polish forming surface, the different shape curved surface. To combine modern numerical control processing and three-dimensional CAD/CAM technology, through the establishment digitization the model, and mark out the reasonable craft parameter and the correct path, we can polish economically and efficaciously on the digitization polishing equipment.

Preferences

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