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Study on Energy Consumption Optimization Method Based on Machine Tool in Intelligent Manufacturing Unit

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Abstract. Manufacturing consumes a lot of energy in the process of turning resources into products or services. The manufacturing process of mechanical products is an important energy consuming manufacturing resource. In response to global warming, improve the sustainable development of the manufacturing and machining of parts for mechanical products manufacturing process is optimized for energy conservation, energy consumption of machine tool bearing gland belongs to typical industrial components. Machining manufacturing process optimization method of energy consumption, this paper studies the machine tool equipment resource modelling and quantitative evaluation on taste, quantitative calculation of energy consumption, mechanical processing and manufacturing process for low carbon manufacturing process planning and production scheduling. Through the application cases of automatic line of bearing gland of machine tool.

Key words: Low carbon manufacturing, Automatic line bearing gland of machine tool, FML, digital factory.

1. Introduction

From the perspective of energy utilization to environmental impact, fossil fuels such as coal and oil belong to carbon-intensive energy. Its emissions of carbon dioxide are a major source of greenhouse gases that are important to global warming. Nearly a third of the world's energy consumption and 30% of CO2 emissions come from manufacturing [1]. The bearing pressure cover mixed flow production line is the intelligent motion control technology [2]. This flexible production line(FML)include Machine tools, tools, fixtures, gauges, conveyor belts, industrial robots, CMM (coordinate measuring machine) and AGV(FMC) [3], Based on the autonomous core technology, the application develops the WiS intelligent factory information system to provide users with intelligent factory solutions from unit intelligence, workshop intelligence to factory intelligence [4].

2. Modelling of energy consumption in machining process.

2.1. Energy consumption model of machine tool

As the processing object of the machine tool, the energy of the input machine tool is used to change the shape, size and surface quality of the workpiece. Energy consumption as a result, the existing machining process modelling research mainly from the angle of the machine tool and the workpiece two research.

Including energy consumption from the viewpoint of workpiece modelling study focused on the machine tool material removal movement of energy consumption, it is the focus of the machining process energy consumption modelling study.

T0 is the beginning time of machining process. ts is the end time of machining process. P(t) is the power characteristic function of the machine tool.

$$E=\int_{t0}^{ts} P(t)\, d(t) \tag{1}$$

It is necessary to analyze the energy flow of machine tool in the process of mechanical process modelling from energy flow transformation.

$$E=P1\times(T1+T2)+P2\times T2+P3\times T3 \tag{2}$$

The energy consumption of the machining process is decomposed into the energy consumption of the process, such as the location, the acceleration of the main shaft, the machining, the change of the knife, and the suspension of the spindle.

P1 represents the fixed power of machine tools that are not related to the running state during machining process, W; P2 represents the material cutting phase of the machining process, W; P3 represents the power of positioning and deceleration during processing, W; T1 represents non-cutting time, h; T2 indicates the cutting time of the material; T3 represents the time of positioning and deceleration of the spindle.

$$E_C = P_C \times t_c \tag{3}$$

EC is the material removal energy, J. PC is the material removal power, W; tc is the material removal processing time, s.

EC is regarded as the energy consumption of machine tool output to workpiece cutting area.

$$P_C=\frac{Fc\times V}{60} \tag{4}$$

Fc is the cutting force when the material is removed,N; V is the cutting speed, m/min;

$$V=\frac{\pi\times D\times n}{1000} \tag{5}$$

D represents the diameter of the workpiece (the turning process) or the diameter of the tool (grinding and drilling), mm; V represents V spindle speed, r/min.

Analysis of energy consumption of material removal model is established through the experiment mainly using the method of box - Behnken and taguchi methods design experiment, and then based on the statistical analysis (e.g., "a yuan regression analysis, the response surface method, neural network, etc.) to establish material removal of the relationship between energy consumption and the selected test factors.

$$P_C=P_0+k\times MRR \tag{6}$$

P0 represents the no-load power of machine tool, kW. MRR (Material Remote Rate) represents the removal rate of materials, cm3/s.

2.2. Energy consumption model of other equipment in FML

The FML also include CMM (coordinate measuring machine), conveyor belts, industrial robots and AGV (Automated Guided Vehicle)

$$E_e=P_0\times T_0+Pt\times Tt \tag{7}$$

P0 is no-load power, W; T0 is no-load time, t. Pt is working power, W; Tt is working time, t.

3. Process of bearing gland

3.1. Function of bearing gland

There is a bearing on both ends of the screw end of the mixture of the two machine tools at T3.3 machine and M1.4 machine, bearing gland shall be installed to seal and locate the bearing. there are two 4×2.5 ring grooves for the inner hole, and the labyrinth seals. Type 2 gland has two threads, It's the effect of reverse locking.

The production line needs to be changed quickly according to different production needs,

$$\frac{\pi\times D\times n}{1000}.$$

And according to the requirement of teaching design one kind of demonstration mode, that is to carry the finished product to undertake not to process, only walk the logistics, the processing, the storage, the unit and the fluctuation material.

3.2. Process analysis

The gland belongs to the disk parts, the surface of the cylinder, groove, inner hole, inner groove and other characteristics need the turning process, the two lathe T3.3 is used for turning the machine, because it takes two clamps. Surface sinkhole, side wall, chamfer need milling machining, Because of the different positioning of the parts, two sets of clamping apparatus are required to be replaced automatically on the working platform of the processing center.

3.3. Process preparation

Bearing pressure cover 1 blank state cylindrical material. The material is 45 steel;2 minutes processing one piece. High tempo requirements. First: use the T3.3 lathe to process the 10 operation(OP10) as Figure 1, tab 1. Use V2 machine tool to process OP10 as Figure3, tab2. Use M4.2 machine tool to process OP30 process as Figure 3, tab 3.

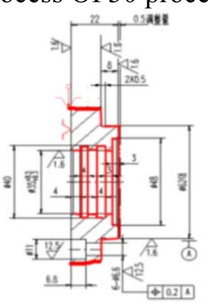

Fig 1. The 10th operation

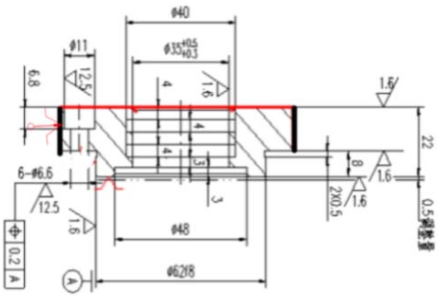

Fig. 2. The 20th operation

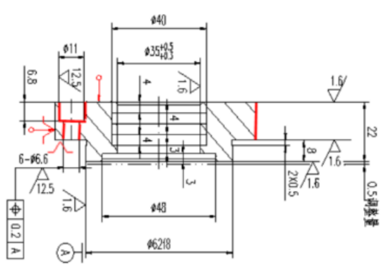

Fig. 3. The 30th operation

Table 1. op10 Cutting parameters

Tool type	Diameter MM	Depth mm	Feed mm/min	Spindle n/min	Tm S	K
Rough turn	33-64	1.5	320	600	47	0.8
grooving	40	0.5	320	600	23	0.3
Finish turn	48-62	0.5	400	2000	12	0.4

Table 2. op20 Cutting parameters

Tool type	Diameter MM	depth mm	feed mm/min	Spinde n/min	tm S	K
Rough turn	35-90	1.5	320	600	47	0.8
Finish turn	35-90	0.5	400	2000	12	0.4

Table 3. op30 Cutting parameters

Tool type	Diameter MM	teeth mm/f	feed mm/min	Spinde n/min	tm S	K
shoulder milling	10	0.04	320	2000	17	0.8
drill	6.6	0.1	320	3200	27	0.5
Vertical milling	11	0.037	400	3600	49	0.4

4. Total automation operation

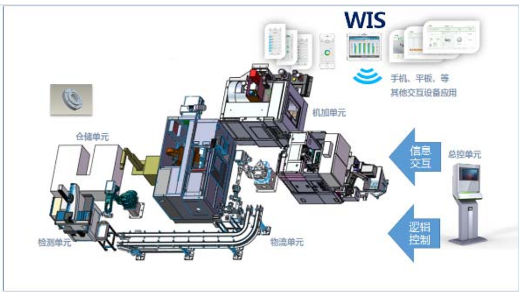

Fig. 4. Automation design

4.1. FML profile

This flexible production line (FML) include machining unit (i5T3.3, i5M4.2 Machine tools), robot(M50,M24),detecting unit (coordinate measuring machine, marposs probe) , logistics unit(machine material storage), also include quick change jig, claw hand for flexible production it's like the figure 6 above. The information collects by enthercat bus line realizationlongic control and PLC information interaction.

4.2. *Matrix in function of flexible production*

The organizational function matrix. The organization object (role) generates information during the execution of the function, and the information object map generates the organization.

In view of the object T represents different artifact types T1 is type1;T2 is type2; In view of the means U represents different automatic unit devices on the automatic line U1/U2 is M24/M50 robot;U3/4/5 is op10/20/30 machine;U6/7 is Schunk gas claw1/claw2 of quick change for M50 robot;U11 is CMM;U12 is laser marking machine;U13/14 is quick manufactures of fixture for op30 machine(soft jaw is made by Schunk), The product of a matrix is just a correlation, it has no mathematical meaning in formula1.

Tab 4. Process flow and operation time.

automatic line operation	Time(t)
op 1: Stock picking	12'
op 2: Transfer channel transit	20.
op 3: R1 feed light inspection type.	30"
op 4: In R1 claw hand	50"
op 5: In M4.2 fixture	40"
op 6: OP10 on the material processing	2'40"
op 7: flip	33"
op 8: OP20 on the material processing	2'50"
op 9: OP30 on the material processing	5'
op 10: flip	33"
op 11: Transfer channel transit	20"
op 12: CMM detection	3'40"
op 13: Qualified marking machine	1'20"
op 14: Unqualified delivery box.	30"
op 15: Finished product back Stock	8"

$$AT_k=\begin{bmatrix} t1 & 0 & \ldots & 0 & 0 & 0 \\ 0 & t2 & \ldots & 0 & 0 & 0 \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & \ldots & tk & \ldots & 0 \\ 0 & 0 & \ldots & \ldots & \ldots & 0 \\ 0 & 0 & 0 & 0 & \ldots & tk \end{bmatrix} \tag{8}$$

$$AP_K=\begin{bmatrix} P1 & 0 & \ldots & 0 & 0 & 0 \\ 0 & P2 & \ldots & 0 & 0 & 0 \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & \ldots & Pk & \ldots & 0 \\ 0 & 0 & \ldots & \ldots & \ldots & 0 \\ 0 & 0 & 0 & 0 & \ldots & Pk \end{bmatrix} \tag{9}$$

$$APkq=AP_{KM}+AP_{KA} \tag{10}$$

$$E=AT_kAP_{Kq} \tag{11}$$

AT_k is the Process time. AP_K is the power of the device. AP_K is divided into AP_{KM} (A machine tool) and AP_{KA} (automatic line other equipment).

According to the operating status of different equipment of the automatic line, the energy consumption calculation model of the whole automatic line can be established through (4)-(11) formula.

Fig 5. the actual digital factory

5. Summary

Based on the energy consumption model of the machine tool, the calculation model of the energy consumption in the process of manufacturing process was established.

Establishing a state evaluation index system for energy consumption of enterprise manufacturing resources will help enterprises to better manage internal manufacturing resources.

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