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The Dynamic Simulation of the Crawling Problems of Machine Tools Based on ADAMS

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Abstract: Because some parts of the machine tool usually demand a very slowly moving or revolving velocity, the machine tool may well occur crawling problems which will affect the processing accuracy of machine tool. In this study the dynamics analysis software of mechanical system, ADAMS, is applied to simulate the crawling problems and the motion instability of the machine tool. According to the line-driven mechanical model of the machine tool, compared with a few main factors which impact the crawling problems, the crawling problems are studied for the optimized results.

Key words: Machine tool, dynamics simulation, stick-slip motion, the motion stability, ADAMS

INTRODUCTION

Some parts of the machine tool usually demand a very slowly moving or rotating velocity. In a low speed movement, although the active component is uniform motion, passive components often appear obvious speed unevenness. As shown in Fig. 1, if the lead screw rotates with constant velocity but worktable may be with non-uniform speed. This phenomenon is called machine tool stick-slip motion. When the machine tool s occur stick-slip motion, it will affect the machining accuracy, precision and surface finish. Therefore, for some precision machine tools and CNC machine tools, it is very important how to improve the motion smoothness of machine to reduce the problem of stick-slip motion (Dai, 1981).

CREEPING PRINCIPLE OF MACHINE TOOLS

The crawling phenomenon will destroy the machining precision and finish degree which can cause scrap or accident. Crawling is a complex phenomenon, the main reasons lies in the difference of static and dynamic friction coefficient; static friction coefficient is higher than dynamic friction coefficient; the mass of moving parts is larger; the lack of transmission rigidity of the machine tool and speed is too low.

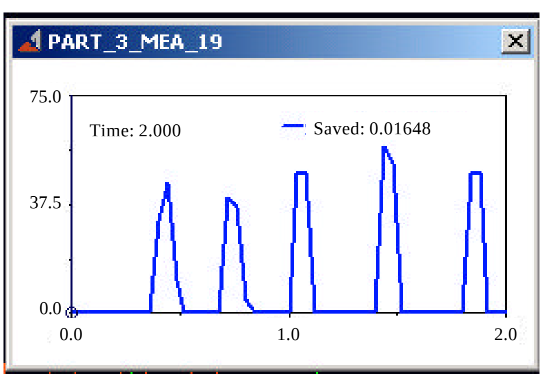

Fig. 1: Worktable crawling phenomenon

Mechanical model of line motion transmission system is as shown in Fig. 2, active part 1 promotes the passive part 3 (Table 1, 2, 3) by the transmission parts 2. Transmission part 2 is a flexible link which can be simplified as a spring. When the active part 1 moves forward to the right with low speed, it compresses spring 2 firstly, then the force is applied to passive part 3. At the beginning it is not enough for the force to overcome the static friction force between part3 and part 4 guide rail, so part 3 does not move. When the active part 1 continues to move forward, the compression amount of spring increases, the force applied to part 3 is bigger and bigger. When the driving force is more than the static friction force, part 3 begins to move. After part 3 begins to move, static friction is turned into dynamic friction, friction force declines immediately, then the speed increases. As the speed increases, the static friction force further reduces (Wang *et al*., 2002).

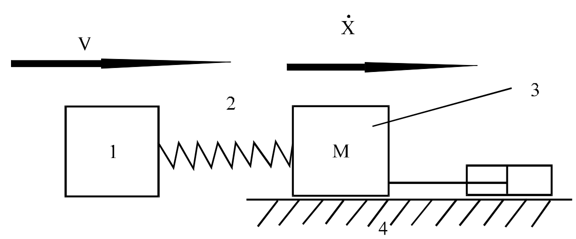

Fig. 2: Mechanical model of linear-driven transmission system

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The energy stored in spring is released which further increases the speed. When energy stored in the spring is released most, the spring recovers elongation, driving force is lowered and speed of passive part slows down. When the driving force is equal to the friction force which reaches equilibrium, the passive component does isokinetic motion. In fact, due to inertia, passive part will go forward for a period of time, so that the spring further elongates and the driving force further declines.

If the driving force cannot maintain passive motion, speed of passive part reduced to zero, there will be some pauses in movement. Then the above process repeats, so does the cycle. The passive part 3 moves discontinuously. If the speed of part 3 is higher, in the end of one cycle which does not reduce to zero, the spring begin to be compressed, the next cycle begin again, the speed of passive part motion is uniform (vibration) but it does not occur stick-slip phenomenon (Zheng, 2002).

SIMULATION OF MACHINE TOOL STICK-SLIP AND PARAMETERS COMPARISON

The stick-slip phenomenon will destroy the machining precision and finish degree, can appear even scrap or accident. Therefore, the phenomenon of creeping should be avoided as far as possible in the process of production. To reduce the friction coefficient difference F, to improve the rigidity K of transmission mechanism, to improve the damping radio and to lower mobile parts quality, can decrease critical speed, then to eliminate the occurrence of the creeping phenomenon. In the following, main factors affecting stick-slip of machine tool are compared, mechanism stiffness K and the static and dynamic friction coefficient difference F, through the simulation to find out the critical speed of creeping phenomenon.

From three curves above, the static and dynamic friction coefficient difference f is smaller, movement more stable and less prone to crawling phenomenon. The friction resistance of the working parts is mainly from the guide rail pair, for a general sliding guide, not only the static and dynamic friction coefficient is large but also the difference is large. So the modern CNC machine tool widely uses rolling guide, unloading guideways, hydrostatic guideway and plastic guideway. High precision CNC machine tools, such as NC three coordinate measuring machine, mostly use air guide. The friction coefficient of rolling guide is small but damping is small; so the vibration resistance is poor, generally the tightening measures are adopted. NC machine tool with common accuracy can adopt plastic guide rail which is cheap, easy manufacture and low price, in addition, the anti-crawling guide rail is another way which can improve the fabrication characteristics. The feed drive system, ball screw nut pair or hydrostatic screw-nut pair is widely used to reduce the friction coefficient difference.

From the above three curves, it is obtained that transmission stiffness is bigger, movement is more stable and less prone to crawling phenomenon. Feeding system from the servo driving device to perform parts must be a transmission chain which consists of the gear, screw-nut pairs or worm-gear pair. The so-called transmission stiffness refers to tensional stiffness and tension and compression stiffness of the transmission chain. In order to improve its stiffness, as far as possible to shorten transmission chain, appropriate to increase the shaft diameter, strengthen the support stiffness. In addition, preload for the bearing, screw nut and the screw can also improve the transmission stiffness.

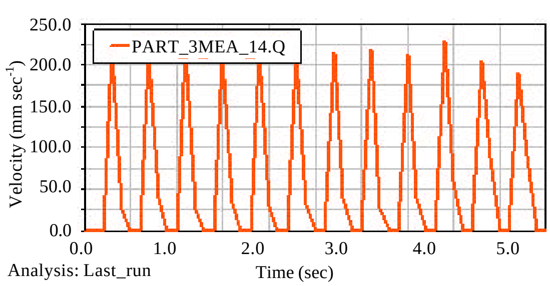

Fig. 3: f = 0.3 the movement of worktable

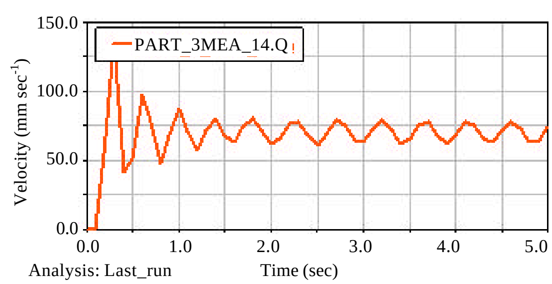

Fig. 4: f = 0.2 the movement of worktable

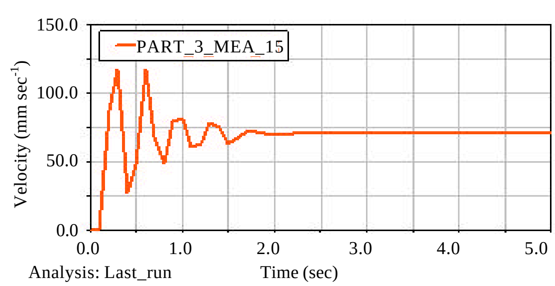

Fig. 5: f = 0.1 the movement of worktable

Table 1: Effects of the static and dynamic friction coefficient difference Δf on crawling phenomenon of machine tool

Name of table	Driving speed (mm min^{-1})	Static and dynamic friction coefficient difference Δf	Transmission stiffness (N mm^{-1})	Crawling and movement stability
Figure 3	70	0.3	800	Crawling and instable movement
Figure 4	70	0.2	800	No crawling but instable movement
Figure 5	70	0.1	800	No crawling and stable movement

Table 2: Effects of transmission stiffness on crawling phenomenon of machine tool

Name of table	Driven speed (mm min^{-1})	Static and dynamic friction coefficient difference Δf	Transmission stiffness (N mm^{-1})	Crawling and movement stability
Figure 6	70	0.3	800	Crawling and instable movement
Figure 7	70	0.3	1500	No crawling but instable movement
Figure 8	70	0.3	2500	No crawling and stable movement

Table 3: Effects of driven speed on crawling phenomenon of machine tool

Name of table	Driven speed (mm min^{-1})	Static and dynamic friction coefficient difference Δf	Transmission stiffness (N mm^{-1})	Crawling and movement stability
Figure 9	10	0.2	1000	Crawling and instable movement
Figure 10	30	0.2	1000	No crawling but instable movement
Figure 11	100	0.2	1000	No crawling and stable movement

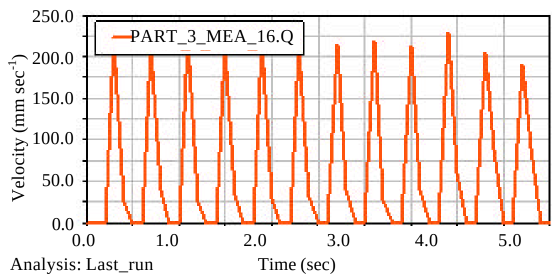

Fig. 6: Movement of worktable when transmission stiffness K = 800 N mm^{-1}

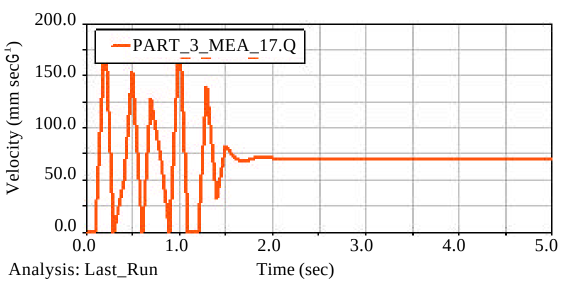

Fig. 7: Movement of worktable when transmission stiffness K = 1500 N mm^{-1}

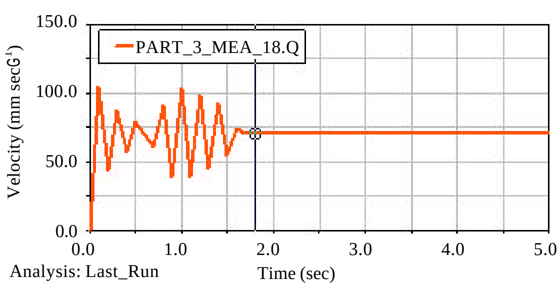

Fig. 8: Movement of worktable when transmission stiffness K = 2500 N mm^{-1}

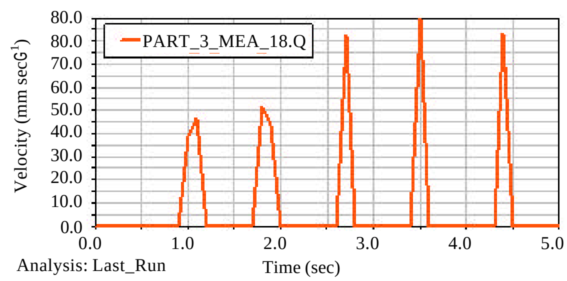

Fig. 9: Driven speed = 10

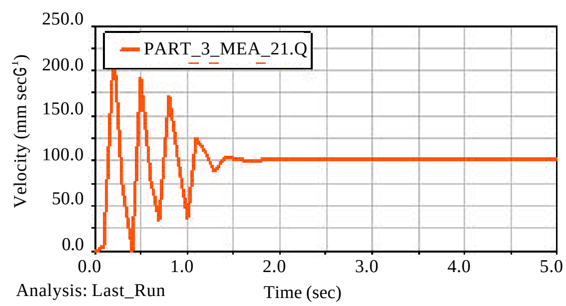

Fig. 10: Driven speed = 30

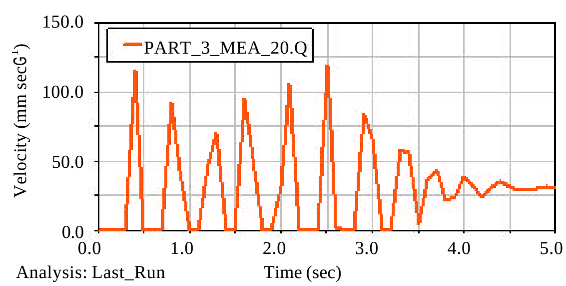

Fig. 11: Driven speed = 100

From the above three curves, it is obtained that driven speed is bigger, movement is more stable and less prone to crawling phenomenon.

CONCLUSION

In this study, the dynamics analysis software of mechanical system, ADAMS, is applied to simulate the crawling problems and the motion instability of the machine tool. According to the line-driven mechanical model of the machine tool, a few main factors is compared, the static and dynamic friction coefficient difference f, Transmission stiffness (N mm^{-1}) which impact the crawling problems and the crawling problems are studied for the optimized results. Different design value is used in the process of parametric analysis to automatically carry out a series of simulation and then return to modify the results. Through the analysis of the parameters, according to the actual production situation, one or more parameters can be analyzed and the optimized prototype model can be obtained creeping change on machine model.

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