The Application of Cutting Condition Monitoring in Aircraft Structural Parts Machining

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Abstract: Based on the experience of using cutting condition monitoring system, the article introduced the basic information of ARTIS system and application methods of the system, the “CTMViSU” and “Learn” modules are represented in detail, some suggestions and further prospects are given out.

Introductions
In recent years, with consistent improvements of advanced manufacturing technology, requirements of the processing efficiency and quality in the manufacturing increase. The quality systems, such as Lean Manufacturing and Six Sigma, put forward higher requirements to the monitoring of the production process. As the monitoring of part manufacturing process depends on the machine’s monitoring systems, many machine tool plants are researching on them. Currently, there are two types of monitoring systems: One is monitoring statuses and various signals of the machine, but this kind of system cannot do any change to the machine running, such as alarm logs of CNC systems (like SIEMENS), monitoring systems developed by some machine tool plants and user-developed third-party software (like DNC). The other one cannot only monitor the status, but also "learn" and record the status, and even do some changes to the machine, such as ARTIS, OMA, etc. This will be mainstreams in the future. At present, the domestic research is confined to the first monitoring strategy. In the meantime, the technical requirements for developers are rigorous, they should acquire the knowledge of software developments and machines’ hardware systems, and have a deeper understanding of process planning and parameters[1].

Introduction to the ARTIS Hardware System
ARTIS system was a set of monitoring systems developed by German ARTIS Company, which could monitor the machining process according to the user requirements. It has achieved tremendous success in the automotive manufacturing. And it has entered the field of aviation manufacturing, though not long. The company is constantly improving and upgrading the ARTIS system according to the features of the aviation manufacturing.
ARTIS system monitors and controls CNC system according to bus signals and sensor signals of the machine tool. At present, it mainly supports three CNC systems: Siemens, FANUC and Rexroth. As the Siemens system is the most compatible for ARTIS, this article will take Siemens system as the example. ARTIS system supports the external sensor detecting system, but this would require another independent display equipment like the ARTIS monitor. ARTIS system can handle a variety of signals: DTA (Digital Torque Adapter) which mainly collects signals of the CNC system; MU4 which gathers power signals; KU4 which collects structure-borne noise signals; CFM-4 which gathers force signals. VG-4 which monitors vibration signals. The most important hardware of the ARTIS system is the CTM card, which has two types: the internal and the external. All the sensor signals are put into the CTM card to process, and then send feedback to the machine. The ARTIS system must contain a CTM card and one CTM card can detect 8 axes.
The following diagram is a typical ARTIS system which contains an external acceleration sensor: The system contains an interface software CTMViSU, which can setup all the parameters of the ARTIS system. The ATRIS system can utilize PLC signals to control the machine tool, and produce all kinds of tips or alarms. The system can automatically monitor processing parameters through the System Bus, and record various statuses, etc. Generally, machine tool plants would complete the system setup for the ARTIS before the delivery, but users can also do some modifications according to their needs.

![Diagam](image)

**Figure 1. The DTA of ARTIS system.**

**Introduction to Interfaces and Parameters of CTMViSU**

The ATRIS system provides numerous monitoring strategies for users. The standard strategy is free and system-provided. The other strategies, such as SAS and dx/dt, and some hardware, functions are optional and need extra expense. The ATRIS system can be controlled by some shortcut keys defined by the machine tool plant, M codes and even the user-defined PLCs.

Monitoring contents of ATRIS system contain three types: the overload monitoring, the breaking monitoring and the missing monitoring. Generally, the System needs several monitoring signals to judge the machining status. When setting up the monitoring parameters, some parameters should be chosen to exclude some interference signals, such as “the baseline” can eliminate the influence of idling, the “Ts” parameters can eliminate the peaks of interference signals in the initial stage, and the “duration” parameters can eliminate the peaks of interference signals in the terminal stage[2].

In the monitoring of dx/dt strategy, Some empirical values are shown in the table below.

<table>
<thead>
<tr>
<th>Name</th>
<th>Assessment Criteria</th>
<th>Standard value</th>
<th>Alarm message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper limit</td>
<td>Sharp rise</td>
<td></td>
<td>Immediate fault alarm</td>
</tr>
<tr>
<td>Lower limit</td>
<td>Sharp down</td>
<td></td>
<td>Immediate fault alarm</td>
</tr>
<tr>
<td>“Missing” limit (pink)</td>
<td>“The Missing trigger conditions”</td>
<td>50%</td>
<td>Signals reduce below the “Missing” limit</td>
</tr>
<tr>
<td></td>
<td>“Missing–1...99%”</td>
<td></td>
<td>Signals reduce below the “Missing” limit</td>
</tr>
<tr>
<td>Overload limit (green)</td>
<td>Over the overload limit</td>
<td>99%</td>
<td>Immediate fault alarm</td>
</tr>
<tr>
<td>Damage limit (blue)</td>
<td>Over the damage limit</td>
<td>80%</td>
<td>Immediate fault alarm</td>
</tr>
<tr>
<td>Passivation limit/Wear limit (red)</td>
<td>Over the passivation limit</td>
<td></td>
<td>Immediate fault alarm</td>
</tr>
</tbody>
</table>
Learning Function

ARTIS system provides a “Learn” function to record the normal status of the processing automatically and adjust the monitoring parameters accordingly. There are two main types: one is the standard monitoring, officially named “the status monitoring”, the other is the dx/dt monitoring, named “the process monitoring”. However, “the status monitoring” is recommended by ARTIS engineers, especially in the batch processing. The ARTIS system can record the monitoring status of some parts which can be compared with the latest status of same parts. If there is a noteworthy difference, the machine tool will be stopped immediately. And then the problem can be tracked through the comparison for these two statuses. “The process monitoring” is used for Real-time monitoring of machine status. Its monitoring foundation is the curves after the "Learn".

In the “Learn” function, all kinds of monitoring parameters are acquired manually or automatically through a normal processing. All kinds of limit values are parts of them, such as the fracture limit is 2 times of peak limit, wear limit is 1.5 times of peak limit, these settings can also be manually modified. To avoid the peak in the process of “Learn” is different from the normal processing, the feed controller must be kept at 100% in this process. The “Learn” process must be conducted at least 3 times. For the first time, the magnification factor can be determined, Secondly, the signal track will be acquired, Finally, the system will activate the monitoring.

The Application of ARTIS System

Compared with auto parts, aerospace monolithic components are complex in structure, numerous in the variety, small in batch and high in requirements of machining accuracy and surface quality, this makes the ARTIS system face severe situation. Based on these characteristics, it’s almost impossible to use the same set of parameters to monitor different process stages of one component, and different components, because of reducing the monitoring reliability. Therefore, different sets of monitoring parameters should be designed to meet needs.

At present, we monitor the process based on structural features. Firstly, we use the “Learn” function to record the statuses of different structural features. Then we can monitor the same structure based on the comparison between the current status and the record. Therefore, feature recognition should be taken into the programming. Unfortunately, the auto-feature-recognition technology is not mature enough to ensure the accuracy.

In order to reduce technical requirements, structural features can be simplified. And milling modes can be divided into 3 categories: the plunge milling, the thread milling and the conventional milling. Each category can be divided into several subcategories. For example, the conventional milling is classified by processing methods and parts. Based on the method, there is rough milling, semi-finish milling and finish milling; based on different parts, there are ribs (ribs, edges and top surfaces), webs, inner and outer shapes (sidewalls), so the conventional milling has nine schemes totally. The above can be added to pre-instructions, and the instructions must be standardized so as to add the relevant instructions for post-processing automatically. However, there is no numbering system for features in ARTIS. The process numbering system of ARTIS can be transformed into the desired feature-numbering system. The ARTIS process numbering system is composed of the following components: position name, program label, T label, D label, machining label. They are the basises of the post-processing. The ARTIS monitoring program is generated by the post-processor according to the pre-instruction and tool informations. Program label represents the milling mode, T label is used to set the tool length, D label is used to set the working length of the tool, machining label can represent the tool Edge radius R. In the meantime, it needs to establish the naming rule of tools in the pre-program, and the tool information must be consistent with the actual information.

The ARTIS cannot only be used to monitor the machine, but also be an effective tool for optimizing programs. In the previous trial cutting, the engineer judge the results of some processing parameters just by some primitive ways, like listening the noise, checking the machined surface, etc.
It is difficult to make it quantitative and automated. With the assistance of ARTIS monitoring system, we can make more objective and scientific judgment and evaluation on the processing parameters. For example, milling spindle manufacturers generally give the user a constant power curve. From the curve, we can obtain the range of constant power speed and the inflection point. Generally we consider that the performance of spindle power and vibration is effective in that range. However, after collecting statuses of all the trial cuttings, we found that no-load curves of tools in different radius were exactly not the same and vibrational characteristics between no-load and loaded situations might not be the same. Therefore, the no-load character of the spindle can only be the reference. And we found that when the machining status is excellent, increasing the speed appropriately will make the machining vibration value smaller and improve the machining efficiency.

In terms of repairs and adjustments, ARTIS can monitor the complete degradation status of the machine tools’ performance. The system can check the degradation status by machining standard parts (such as Laplace test pieces and S test pieces) at different time. Meanwhile, we also can determine the exact time when some mechanical statuses of machine tools degenerate and analyze the reasons through the analysis of current and power signals.

Two aspects should be paid attention in the application of ARTIS:

1. The appropriate process monitoring parameters acquired by “Learn” function should base on a considerable number of basic data (including different structural features, different processing modes, different tools)

2. How to regulate the operators’ treatments to the ARTIS monitoring alarms? This will need specialized technical engineers and operators track on-site problems for a long time to grasp statuses of various abnormal situations and regulate standard treatments.

Overview

ARTIS system is significantly powerful, but some functions still cannot be used well, and even are ignored by some users. Technical level of users decides whether or not some functions are available, such as the self-adaptation control. This function can improve the efficiency of the machine tool effectively. However, it will require the engineer to provide reasonable parameters for the system to adjust automatically, and judge the status of the machine by the abnormality of noise, vibration, current, temperature and so on. At present, it is just suitable for the rough machining.

The ARTIS allows technical users to do secondary developments. For instance, the system can change the tool automatically when the abnormality occurs. Once the tool wear monitoring alarms, the system will locate the break point in the NC Codes, lift the tool in the normal direction and measure its length. Based on the length measurement, the system will decide whether to change the tool.

In the meantime, the ARTIS system should be promoted. For instance, when some abnormal alarms occur, we can't pause the monitoring process manually. For some unavoidable operations, such as executing a single program, setting the electric potential feed controller as 0%, the ARTIS system will all regard these as abnormalities. And the ARTIS system takes up too much resources, so the speed of the PCU will drop after a long time running.

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References