MACHINE TOOL GENOME PROJECT

NATIONAL CENTER FOR DEFENSE MANUFACTURING & MACHINING

The University Of Sheffield.
Advanced Manufacturing Research Centre

BOEING

BlueSwarf
THE PERFECT CHIP

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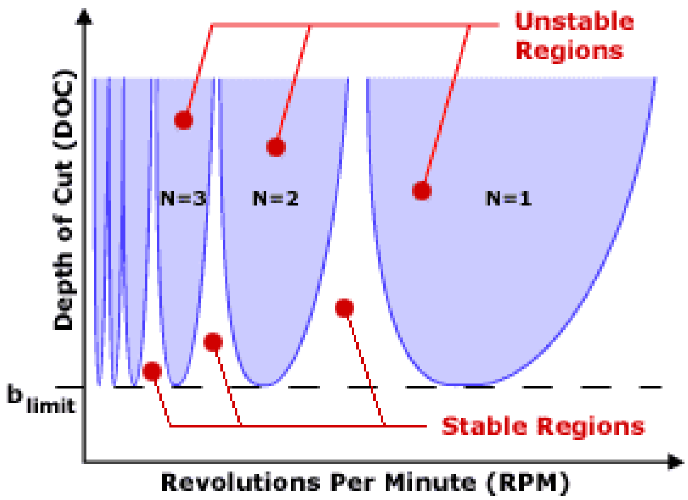

Optimization of the cutting performance of modern and legacy machine tools is a critical factor in cost containment and cost reduction in the aerospace and defense manufacturing sectors. Inefficient use of machine tools directly and negatively impacts the cost of every machined component. Without proper measurement and optimization of the cutting performance of machine tools, it is not uncommon for machine tools to be under used by a factor of four or more.

What is Chatter?

The onset of chatter during machining is primarily a function of the variation in chip thickness that occurs due to vibration of the tool, workpiece, or both. The flexible tool engages the workpiece and, due to the cutting force, begins vibrating. This vibration is imprinted on the machined surface. In milling, the next tooth on the rotating cutter overcuts this wavy surface produced by the previous tooth. This wavy surface varies the instantaneous chip thickness which, in turn, modulates the cutting force and the cutter vibration (i.e., a feedback mechanism is produced that can lead to self-excited vibrations, or chatter). Depending on the relationship between the wavy surface left by the previous tooth and the current cutter vibration, the resulting deflections and forces can grow very large (chatter) or diminish (stable cutting). Excessive vibration and chatter costs manufacturers $100 Billion annually in lost productivity.

Vibration phenomena are not random, but rather they can be quantitatively measured and described. With the aid of advanced technology, it is now possible to scientifically quantify the vibration characteristics of a milling process, predict chatter, and make recommendations to eliminate it. However, it is important to recognize the degree of analysis that is required. Chatter has a direct impact on surface finish, tool life, cycle time, and cost. Understanding the priority of one or more of these variables in a given operation is crucial to successfully eliminating chatter and substantially optimizing specific milling operations.

New Technology Delivery System, the BlueSwarf Dashboard™

Due to a lack of engineering support and limited knowledge of dynamic testing procedures, the frequency response measurements are rarely carried out, especially at Tier I and II facilities that fabricate a large fraction of the total number of U.S. discrete parts due to outsourcing from major aerospace and defense manufacturers. Therefore, the well-established BlueSwarf™ stability improvement technology (i.e., stability lobe diagrams, which separate stable and unstable cutting zones graphically as a function of chip width and spindle speed afforded by high-speed machining is very often not applied. The result is reduced process efficiency and part quality and increased cost. The development of this Internet-based data collection (MetalMax™ DC) and information delivery (BlueSwarf Dashboard™) platform described here will require no specialized knowledge from the user. The purpose of the Tool Dashboard™ is to allow users, without extensive knowledge of chatter theory or mechanical vibrations, to take full advantage of the available improvements in process efficiency. BlueSwarf Dashboards™ allow process planners to select high-speed milling parameters for maximized material removal rates in a science-based pre-process manner, rather than relying on experience or trial and error testing. The primary mechanism for realizing this capability is dynamics prediction for the tool/holder/spindle/machine assembly.

Compatible with TOMS, TDM and CATIA

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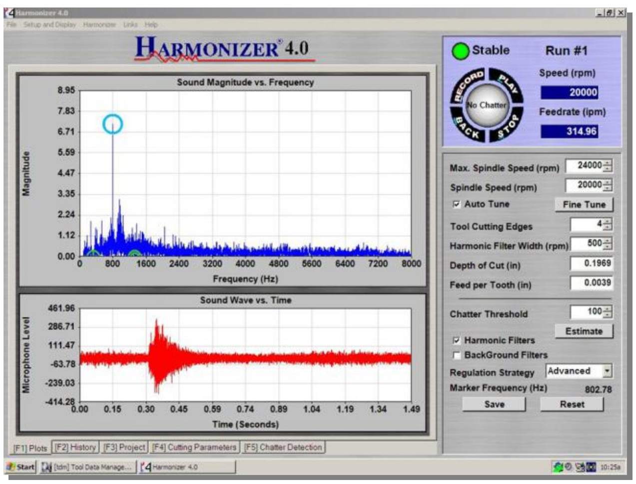
MLI High Performance Machining Specialists

In the UK, contact:

AMRC MANUFACTURING LIMITED

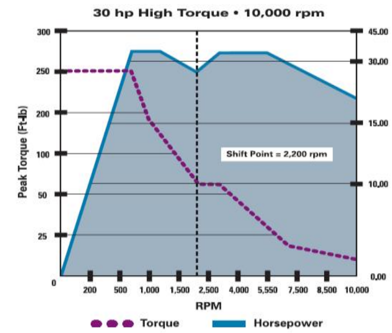
New Data Collection System, the MetalMAX™ DC

Through the introduction of our new easy-to-use MetalMax™ Data Collector, we eliminate the primary impediment to full implementation of the academic research in high-speed machining, particularly linear and nonlinear chatter (or unstable machining) models. The MetalMax™ DC enables quick measurement of each tool/machine combination's frequency response with impact testing where an instrumented hammer is used to excite the structure and the response is recorded using an appropriate transducer, such as an accelerometer. The data collected is encrypted and sent via the internet to our engineers who analytically predict the assembly response by combining the measurements of the individual components with empirically-obtained parameters regarding the machine tool and cutter limits. The chatter models, which can be used to select cutting conditions for both dramatic increases in material removal rates and improved part accuracy, require knowledge of the system frequency response as reflected at the tool point. The results of this analysis are presented graphically and interactively in BlueSwarf Dashboards™. Parameters of the machine/spindle/holder substructure (including the spindle specifications such as top speed and available power and torque), cutter material and geometry, workpiece material and radial immersion are combined with the tool point frequency response function (FRF) measurement. Based on this information, recommendations for chip load and maximum surface speed are made using parameters provided by the tool manufacturer. The data presented to the user in the BlueSwarf Dashboard™ includes the stability status, corresponding spindle speed-dependent material removal rate (which may be machine specific power or torque limited in some instances), and recommended milling operating parameters, i.e., spindle speed, axial and radial depths of cut. Due to temperature-driven chemical/diffusive wear, an upper bound on surface speed is imposed on the stability lobe-based spindle speed. In this case, the selected spindle speed can revised to avoid excessive tool wear, while still maintaining a reasonable depth of cut. Feed rates are re-calculated to compensate for chip-thinning caused by low width of cut engagements. Bending moment limitations are calculated based on drawbar gripping forces and tool projection. The user is given the option of choosing between maximizing metal removal rate or tool life.



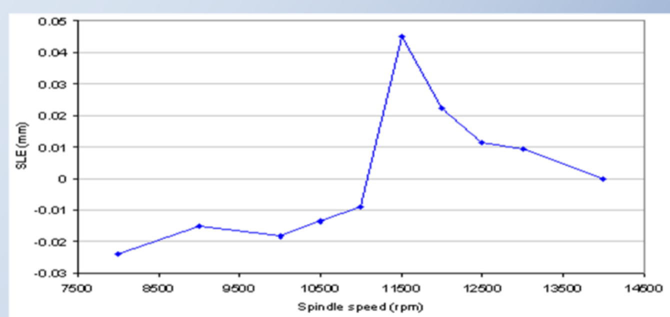
Once a stable spindle speed and cutting depths are determined using the BlueSwarf Dashboard™, the optimized cutting can be validated and maintained using our patented Harmonizer® software. The RPM at which a cutter spins combined with the cutter diameter and number of teeth is responsible for creating the tooth passing frequency. Based on the engagement conditions, the relative magnitude of sound is recorded, and the level of cutting stability is recognized. This system follows a strict set of rules so as to eliminate regenerative waviness and hence eliminates any newly induced chatter by making an RPM recommendation which would put the system back in a stable cutting region. The sound file can be saved and uploaded to BlueSwarf for high level analysis and archiving. Over time, new sound files can be compared to the initial baseline recording to detect possible service issues.

How BlueSwarf™ Saves Energy - The chart at the right is a typical torque and horsepower curve of a machining center spindle. Spindles are designed to provide low end torque and power for rough machining at slower speeds.



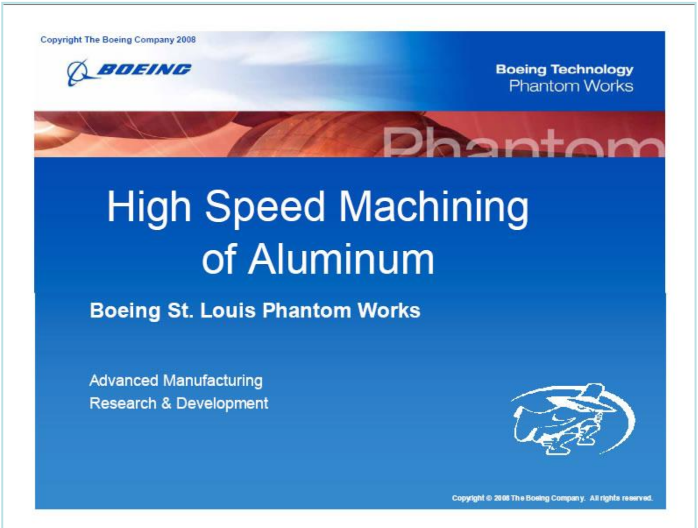
As speeds increase the power and energy consumed is reduced. One Kilowatt (kW) of energy is consumed for each 1.34 unit of horsepower required. In this example, at 6000 RPM, 22.4 kW are consumed. At 10,000 RPM, only 13.4 kW are needed, a 40% reduction. BlueSwarf technology allows tools to run at the highest possible RPM, thus reducing the energy required. In addition, BlueSwarf enables deeper, more productive cuts reducing the energy consumed per part produced.

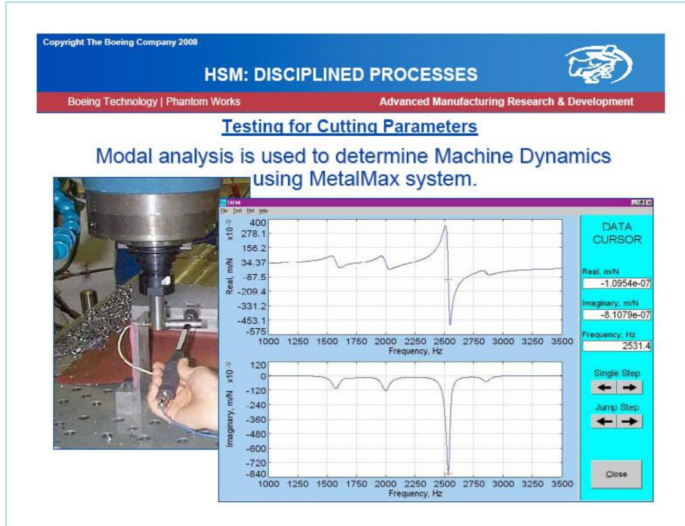
How BlueSwarf™ Improves Quality - This chart shows the relationship of Surface Location Error



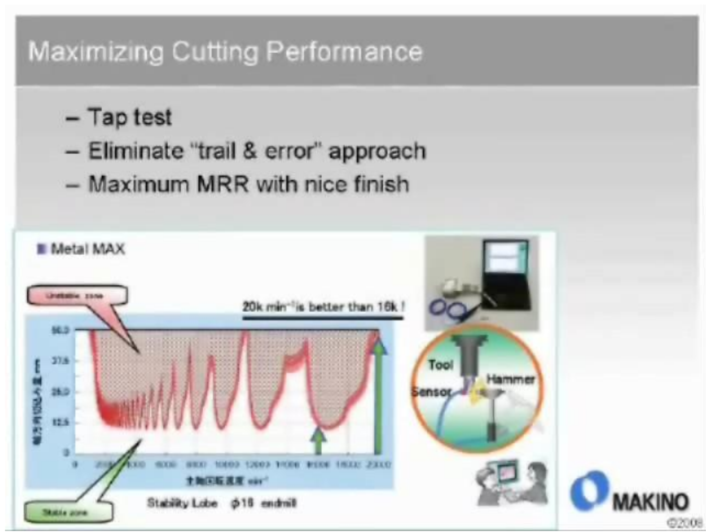
(SLE) and spindle speed (RPM) as calculated by BlueSwarf's engineers using time-domain simulation. Even under stable cutting conditions, the tool experiences forced/synchronous vibrations that may lead to under or over cutting the commanded dimension in the part program. Therefore the highest metal remove rate may not provide the highest repeatability. This may be acceptable for roughing but not for high accuracy finishing requirements. We can determine the optimal speed for the highest accuracy and quality. In this instance the speed with the lowest SLE was 13,800 RPM. This was not the location of the highest metal removal rate, but was appropriate for the light radial immersion of a finishing pass.

Boeing PhantomWorks Uses BlueSwarf MetalMax™ Technology





Makino Recommends BlueSwarf MetalMax™ Technology for Aerospace Machining



The NCDMM Uses and Recommends BlueSwarf MetalMax™ Technology

GSA IDIQ Contract Holder

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BlueSwarf MetalMax™ enabled over $1 Billion in savings on the F/A-18 E/F

Read our March Cover Story in MODERN MACHINE SHOP