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Reduction of noise during milling operations

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ABSTRACT

With the increase in performance of machining operations, noise levels have become an occupational health and safety problems. Identification of the main sources of noise emission when milling an aluminium component was analyzed. A machining centre, equipped with microphones, was installed in an anechoic chamber. Testing demonstrated that the part's stiffness is the most critical parameter. Cutting speed, feed and axial depth of cut tend to increase sound pressure level by increasing the impact energy, whereas radial depth of cut is not a sensitive parameter. Moreover the diameter of mills, as well as their unbalance, should be limited.

Introduction

The main challenge for manufacturing plants is to produce parts at low cost. During the last 20 years, manufacturers of machine tools and cutting tools have developed new technical solutions, such as high-speed machine tools, or increased of mechanization, leading to great productivity improvements and reduction of labour costs. In recent years, environment impact has become an additional challenge. Decreased use of chemical products, such as cutting fluids and reduced energy consumption are clear examples.

An additional challenge is to limit the Occupational Health and Safety problems (OHS) impact of manufacturing plants on operators. Among the aggressions undergone by operators in a machining workshop, noise is a critical phenomenon since it affects them daily without any obvious short-term impact on hearing [1]. The long-term consequences, however, are dramatic for operators and costly for companies. Machining of aluminium parts (crankcase, cylinder head, etc.) is a clear example of this, where operators are exposed to high noise levels, especially in big workshops with a large number of machines with limited space between them [2,3]. The European regulation 2003/10/EC indicates two daily noise exposure levels for 8 working hours: (i) below 80 dBA, no protection is recommended, (ii) over 85 dBA, protection is necessary and the company must initiate a programme to reduce noise emission. Between 80 and 85 dBA, the company must offer individual protection to the operators and to test their hearing capacity annually. The critical daily noise exposure level of 85 dBA is often exceeded in the manufacturing industry [1,3].

As a consequence, technological advancements are needed to improve noise emissions of machining. A first solution consists of encapsulating the whole machine, which is not realistic in production system that requires operators. A second solution can consist of adding silencing equipment, which is always costly. A third solution is based on new machine components with passive damping components [4] or active mechanical components [5]. These approaches are valid for new investments but not for current machine-tools, that represent the vast majority of production systems.

So, a more effective strategy may consist in developing new machining strategies that limit noise emission.

Among all the noise sources during a cutting operation in a machining centre, almost any electrical and mechanical components of a machine-tool can generate noise (power supply, hydraulic systems, pumps, chip evacuation, air pressure leakage, etc.) even without any cutting operation [1]. In contrast, the cutting tool and the part can only generate noise when the cutting operation is in progress. Static components such as the fixturing and the mechanical structure can also generate noise due to the mechanical excitation of mechanical components induced by the cutting process.

In the case of machining an aluminium crankcase, preliminary research [6] showed that among all the cutting operations employed in the manufacturing of a crankcase in a plant, milling operations generate the highest sound pressure level (commonly higher than 100 dBA at a distance of 40 cm from the cutting zone – Fig. 1). Other processes such as drilling, tapping and reaming

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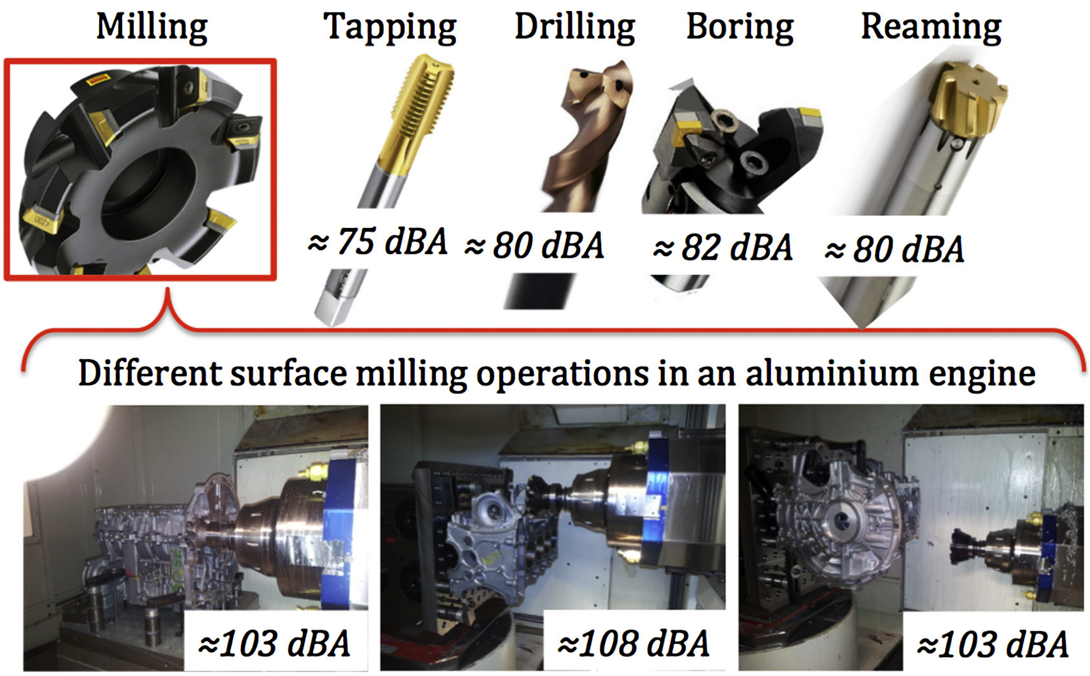

Fig. 1. Comparison of average sound pressure level emitted by various cutting technologies during the machining of an aluminium crankcase.

generate a sound pressure level of around 80 dBA. So, to reduce the noise emission in a workshop, it is necessary to focus on the milling process.

Most of the research carried out in machining or cutting to date has not considered the reduction of noise as the main goal. Several articles dealing with the monitoring of cutting tool wear [7–9] can be found in the literature, but unfortunately, most of them only consider high acoustic frequencies (>100 kHz), which are outside the range of human hearing (max. sensitivity between 1 and 5 kHz). Some authors also use sound emission analysis in order to detect chatter vibrations [10–12], but again they do not pay attention to relationship between sound pressure level and human hearing, nor do they consider the legal threshold.

This paper identifies the parameters that most influence noise emissions in a milling operation of aluminium parts. Then new milling strategies to reduce noise levels are proposed.

Development of an anechoic chamber

The characterization of noise emitted by a machining centre located in a workshop can be difficult since the all the equipment in the vicinity disturb noise measurements. Moreover, even if all the equipment is switched off, the enclosures and the walls of the buildings reflect noise, which disturb measurements [4]. For this reason, it is necessary to make such measurements in an anechoic chamber. An anechoic chamber with a hard floor was specially designed and built around a PCI METEOR 5 machining centre. The machining centre is a 4-axis horizontal machine typically used to produce aluminium parts in automotive machining plants. The dimensions of the chamber are presented in Fig. 2. The inside walls are built from ROCKFON® stone wool acoustics ceiling (ISO11654 absorption coefficient α_w in the range 500–5000 Hz) so as to avoid noise reflection and transmission from outside. In contrasts the outside walls consist of metallic cladding so as to facilitate external noise reflection.

It is worth mentioning that the cooling pump and its climatization system have been located outside the anechoic chamber. Indeed, in most industrial machining workshops, there is a single hydraulic system for the entire workshop. This equipment is usually installed far from the machining centre, which cannot induce noise disturbances for operators close to the machining area.

A data acquisition system was installed to collect milling process sound through two ½″ condenser microphones. One was placed inside the machine-tool enclosure (Fig. 2, micro 1 at 40 cm away from the cutting zone) and the other where operators are commonly installed to check cutting operations in front of the CNC system (Fig. 2, micro 2). Sounds were analyzed by sampling the signal of the microphones with a frequency up to 48 kHz. The signals were post-processed with a A-weighted filter in order to estimate the noise level in dBA within the range of the response to sound of the human ears. Finally, a spectral analysis was performed using the Fast Fourier Transform (FFT) algorithm to identify dominant frequencies.

Sensitivity study of sound pressure level

A sensitivity analysis was carried out to evaluate the most critical parameters of noise emission in the following machine states:

- First set of experiments: Switching on and off the machine tool (without milling).
- Second set of experiments (without milling): Rotation speed, tool diameter and tool balancing.
- Third set of experiments (in milling): Cutting speed, axial depth of cut, radial depth of cut and feed per tooth, part stiffness ratio.

Noise emission of the machine switched on and off

The first set of experiments analyzed the noise emission when the machine tool was switched off and on, without milling.

When the machine and air pressure admission were switched off, the sound pressure inside the anechoic chamber in the operator's zone (Fig. 2, micro 2) was around 42 dBA, whereas it was only 39 dBA in the cutting zone (Fig. 2, micro 1). As the sound in the operator's zone was higher, it means that the idling sound comes

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