euspen's 23rd International Conference & Exhibition, Copenhagen, DK, June 2023
www.euspen.eu

Effect of lead addition on machinability of brass and its mechanism

Kosuke Sumiyoshi[1), a)], Hiroo Shizuka[1)], Katsuhiko Sakai[1)], Takuro Ando[1)], Kazuhito Kurose[2)], Hisanori Terui[2)]

[1] *Shizuoka University, 3-5-1 Johoku Naka-ku Hamamatsu Shizuoka 432-8561 Japan*
[2]*Kitz Metalworks Corporation, 7377 Kobayakawa Miyagawa Chino Nagano 391-8555 Japan*

[a)] *sumiyoshi.kosuke.18@shizuoka.ac.jp*

Abstract
In recent years, raw material suppliers have developed several types of lead-free brass by adding Bi or Si. However, the machinability of these brass types is considerably less than that of conventional free-cutting brass. Therefore, the effect of lead on the free-cutting properties of brass must be determined to develop lead-free brass with high machinability. In this study, orthogonal cutting with varying lead concentrations was performed to investigate how the addition of lead affects machinability. The results show that the addition of approximately 1% of lead reduced the cutting force and coefficient of friction. However, the results of cutting temperature measurements and observation of the chip generation process suggest that lead does not reach its melting point during this process. The improvement in the machinability due to lead addition is generally attributed to the melting of lead caused by the heat generated during cutting, which results in a low coefficient of friction. Thus, the improvement in machinability is also due to the change in chip shape, which reduces the contact length between tool and chip and subsequently reduces the friction coefficient

Keywords: Brass, Orthogonal Cutting, machining

1. Introduction

Generally, brass with lead added to it is called free-cutting brass and is used as a material for various components, such as water supply parts. However, the use of lead is regulated by RoHS and ELV directives in many countries because it has adverse effects on the human body[1, 2]. Therefore, raw material suppliers have recently developed several types of lead-free brass by adding Bi or Si. However, lead-free brass is more difficult to machine than conventional free-cutting brass[3]. Therefore, the underlying cause of the free-cutting properties induced by adding lead must be identified to develop an optimal method for producing lead-free brass with high machinability. In this study, orthogonal cutting experiments were conducted with varying lead concentrations to investigate the effect of lead addition on machinability.

2. Experimental apparatus

In this study, free-cutting brass with different lead concentrations was used. Figure 1 shows an overview of the experimental apparatus. The orthogonal cutting apparatus was designed for cutting at a maximum speed of 180 m/min. Further, the work material was fixed to a linear motor-driven table, which was driven at a constant cutting speed. The tool used was an uncoated carbide insert (Mitsubishi Materials TPMN160304-UTI20T) with a rake angle of 5° and a clearance angle of 6°. The cutting forces were measured using a three-component force sensor (Kistler Type 9601A) and charge amplifier (Kistler Type 5011) connected to a data logger (GRAPHTEC GL900). Cutting temperatures were measured at the contact point between the tool and the workpiece using the tool-workpiece material thermocouple method.

3. Experiment

3.1. Orthogonal cutting experiments with varying lead concentration.

Orthogonal cutting was performed by varying the lead concentration in 0.5% increments from 0.5% to 2.5%. Two experiments were performed. Table 1 lists the chemical compositions of various materials. The cutting forces, cutting temperatures, friction on the rake surface, and shear force on the shear surface were calculated according to the orthogonal cutting theory[4]. The experimental conditions are listed in Table 2. The cutting width in this experiment corresponds to the turning feed. Figure 2 shows the results of cutting force measurements and cutting temperature measurements, and Figure 3 shows the friction coefficient. Figure 2 shows that at a cutting speed of V = 50 m/min, lead concentrations as low as 0.5% significantly reduced both the cutting resistance and friction coefficient compared with brass without lead. This confirmed that even a small lead concentration (approximately 0.5 %) improved machinability. Figure 2 shows that the cutting temperature is less than 330 °C, the melting point of lead, suggesting that lead does not melt during cutting and is thus not the reason behind the improvement in machinability.

3.2. Cutting experiments at a cutting speed of 1 m/min

Although Figure 2 shows that the lead does not melt, a local temperature increase could result in the melting of lead. Therefore, extremely precise cutting at a cutting speed of 1 m/min was performed and the same experiment was repeated under conditions where the temperature increase was almost negligible. In this experiment, chip formation during cutting was observed with a high-speed camera. The experimental conditions are listed in Table 3. Figure 4 shows the results of cutting force and temperature rise measurements during cutting, Figure 5 shows the results of friction coefficient calculation, and Figure 6 shows the results of high-speed camera observation. Figure 4 shows that adding lead reduces the cutting force and friction coefficient for cutting temperatures where the lead does not melt. This observation is consistent with that in a normal cutting speed of 50 m/min. Figure 6 also shows that adding lead reduces the contact length between the tool and the chip. These results show that adding lead changes the chip shape and reduces the tool-chip contact length when cutting at a speed of 1 m/min. Consequently, the friction coefficient is reduced, which reduces the cutting force.

4. Conclusion

[1] The addition of small lead concentration (0.5%) improves the machinability of brass.
[2] The addition of lead reduces cutting forces even at a cutting speed of 1 m/min, where the temperature rise is negligible.
[3] The reason behind the reduced cutting resistance is the change in chip geometry caused by the addition of lead. This change results in a shorter tool-chip contact length, which reduces the friction coefficient.

References

[1] K Watari, T Iwasaki and T Aiso 2016 *Nippon Steel Technical Repor* **406**
[2] M Takuma, T Sato, K Saitou, Y takahashi and Y Hirai J 2022 *Transactions of the JSME (in Japanese)* **88** 908
[3] K Oishi, H Goto and K Suzaki 2020 *Materia Japan* **60** 110

Table 1 Chemical composition with different amounts of material added : mass%

	Cu	Pb	Zn
Lead0%	60.0	-	bal.
Lead0.5 %	60.0	0.5	bal.
Lead1.0 %	60.2	1.0	bal.
Lead1.5 %	59.1	1.6	bal.
Lead2.0 %	60.5	1.9	bal.
Lead2.5 %	60.4	2.4	bal.

Table 2 Cutting conditions

Cutting speed m/min	50
Depth of cutting mm	0.05
Cutting width mm	3
Atom.	Dry

Table 3 Cutting conditions

Cutting speed V / m/min	1
Depth of cutting d / mm	0.05
Cutting width a / mm	3
Atom.	Dry

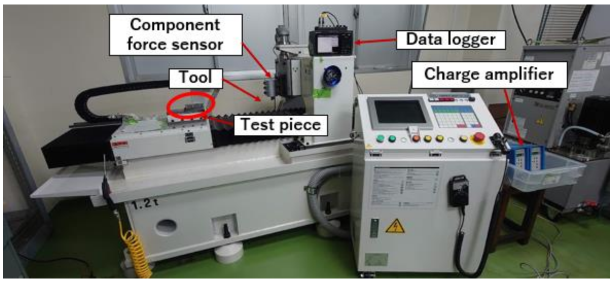

Figure 1 Over view of experimental apparatus

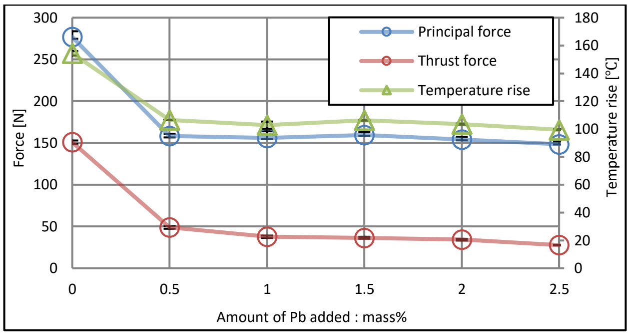

Figure 2 Cutting force measurements and Cutting temperature measurements

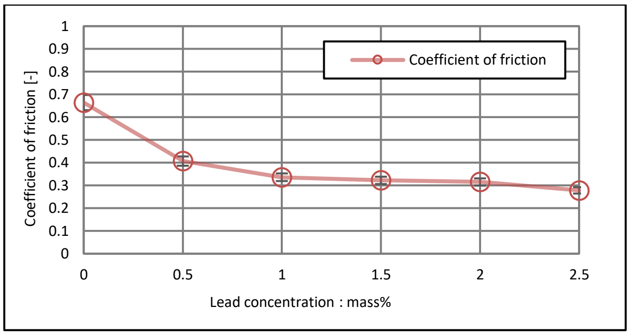

Figure 3 Friction coefficient

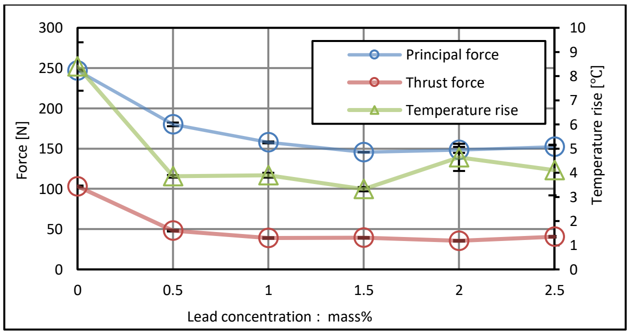

Figure 4 Cutting force and temperature rise measurements at a cutting speed of 1 m/min

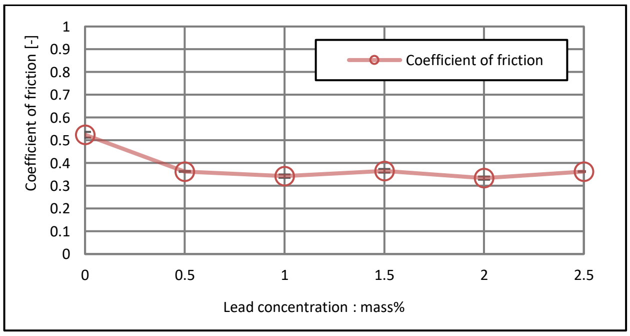

Figure 5 Friction coefficient at low cutting speed

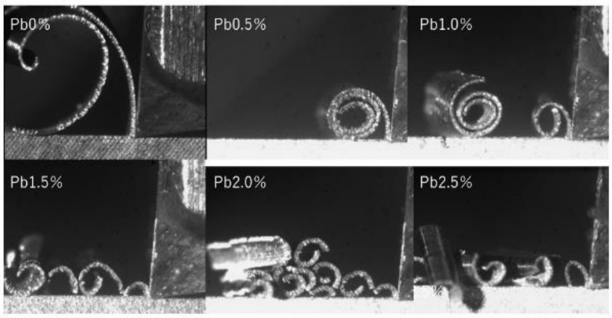

Figure 6 High-speed camera observation at low cutting speed