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# Friction factor of CP aluminium and aluminium–zinc alloys

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**Abstract. Friction factor has been determined for CP aluminium and aluminium–zinc alloys using ring compression test at different temperatures from 303 K to 773 K. It is found that CP aluminium exhibits sticking whereas Al–Zn alloys do not exhibit sticking at elevated temperatures. Hot working of Al–Zn alloy is easier than that of CP aluminium at 773 K. As zinc content increases up to 10 wt% the friction factor decreases up to 0·02.**

**Keywords. Friction factor; sticking; sliding; aluminium; zinc.**

## 1. Introduction

Friction plays an important role in metal forming. In processes like rolling, it is desirable and essential. In processes like extrusion and forging, it is detrimental and should be minimized even if it cannot be eliminated altogether. There are two types of friction viz. sliding friction and sticking friction (Mielnik 1991; Saha 2000). Both of them can be quantified by either friction coefficient ($\mu$) or friction factor ($m$). But, friction factor is advantageous (Dieter 1988). Friction coefficient, $\mu$, decreases inversely with interface pressure and can lead to misinterpretation of frictional forces. On the other hand, friction factor, $m$, is independent of normal stress at the interface. Moreover, it can easily be measured and also leads to a mathematical simplification of analysis of forces for metal working processes. Ring compression test can be used to determine $m$. The deformation of ring is shown in figure 1 for zero friction, low friction, high friction and sticking friction (Altan *et al* 1983; Schey 1983).

## 2. Experimental

Aluminium rods were melted and alloyed with zinc to get alloys of 5%, 10%, 15%, 20% and 25% zinc. Rings of (6 : 3 : 2) outer diameter, 24 mm, inner diameter, 12 mm and height, 8 mm, were machined from CPAl and Al–Zn alloys and annealed in a furnace at 773 K for 1 h. These rings were compressed and tested in the 250 T hydraulic press with graphite as lubricant. The schematic set up is shown in figure 2 and the ring specimens before and after compression are shown in figures 3a–c (Wagoner and Chenot 1997) The test was carried out at 773°K for Al–Zn alloys and for CP aluminium at temperatures 303, 373, 473, 573, 673 and 773 K. The reduction in height and decrease in internal diameter were measured and using the calibration chart (Male and Cockroft 1964–65) shown in figure 4, the friction factor was estimated. The Rockwell hardness of all the samples were also measured.

## 3. Results and discussion

Friction factor, $m$, of CP aluminium is given in table 1 for various test temperatures. The friction factor, $m$, was low (0·09–0·34) up to 673 K but it reached 0·90 at 773 K exhibiting sticking behaviour. Figure 5 shows the plot of friction factor for alloys with increasing zinc size up to 25 wt% at 773 K. Hardness of all these alloys and CP aluminium are shown in table 2. It was found that $m$ value decreases with 10 wt% Zn and remains unchanged up to 25 wt%.

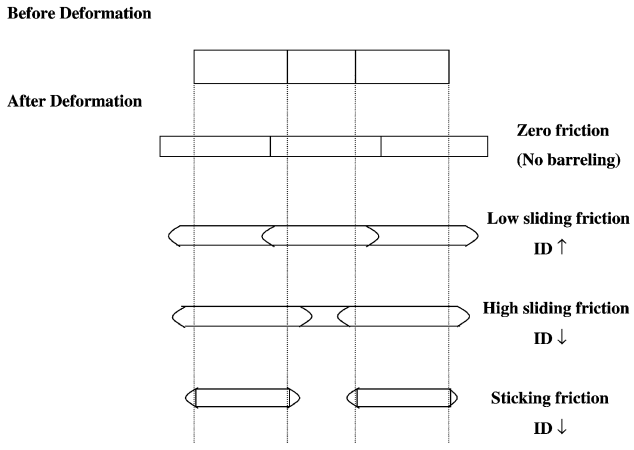


**Figure 1.** Types of ring deformation after compression.

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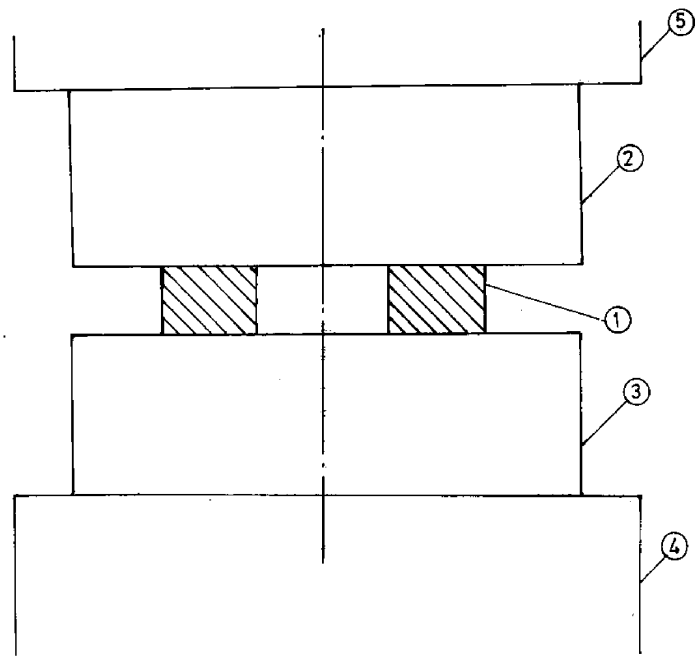


**Figure 2.** Schematic set up of ring compression test.

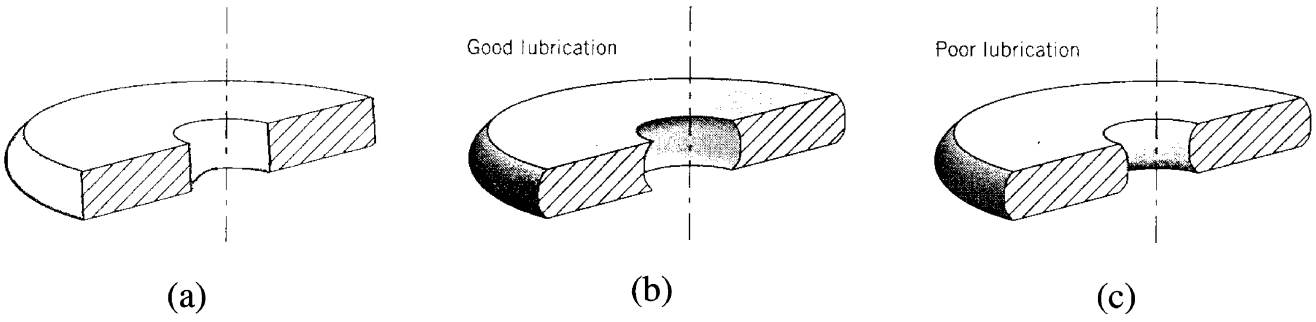


**Figure 3.** Ring specimen (**a**) before compression, (**b**) after compression with low friction and (**c**) after compression with high friction.

**Table 1.** Friction factor at different temperatures for CP aluminium.

| Temperature (K) | Friction factor ($m$) |
|---|---|
| 303 | 0·34 |
| 373 | 0·09 |
| 473 | 0·18 |
| 573 | 0·30 |
| 673 | 0·14 |
| 773 | 0·90 |

**Table 2.** Hardness at room temperature for different compositions.

| Composition | Hardness ($R_B$) |
|---|---|
| Al | 11 |
| Al–5%Zn | 20 |
| Al–10%Zn | 31 |
| Al–15%Zn | 63 |
| Al–20%Zn | 50 |
| Al–25%Zn | 39 |

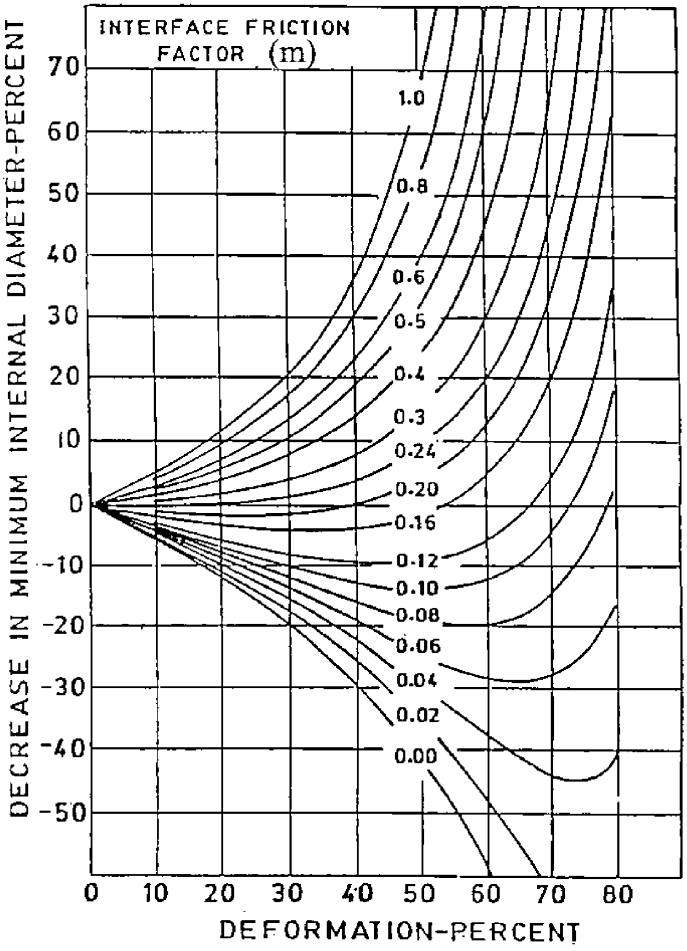


**Figure 4.** Calibration chart for finding friction factor.

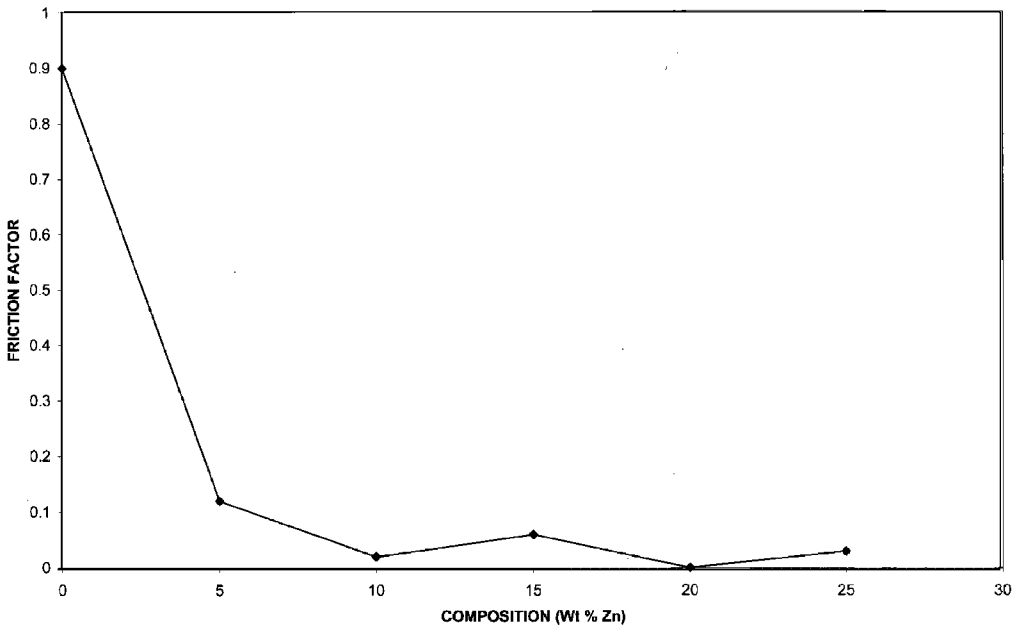


**Figure 5.** Plot of friction factor against composition.

CP aluminium tends to stick to the tools at elevated temperatures because it is soft and gummy. It has a very high friction factor of 0·9 at 773 K. This is disadvantageous in hot forging components out of CP aluminium. Alloying with zinc reduces sticking to a great degree. In fact, it almost eliminates the phenomenon.

## 4. Conclusions

(I) CP aluminium has low (up to 0·3) friction factor up to 673 K and safe to work but it increases to 0·9 at 773 K causing sticking during hot working.
(II) Addition to 10 wt% Zn in CP aluminium lowers the friction factor up to 0·02 rendering easy hot workability.

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