THE WEAR CHARACTERISTICS OF SOME ALUMINIUM-SILICON EUTECTIC-BASE ALLOYS.

BY

M.S. SAMI* and S.IBRAHIM**

ABSTRACT

The wear behaviour of the aluminium-eutectic base alloy is examined along with the modified entectic alloys containing varying copper additions and a constant amount of Mg and Ni which are used to improve the strength of the alloys. The wear tests are carried out for the various alloys either in the as-homogensized state or after aging treatment, at constant sliding speed and different loads. The results are examined in order to determine the optimum condition for wear resistance.

* Welding electrode factory.

** Met. Dept, Faculty of Pet & Mining Eng., Suez Canal University, Suez.

I. INTRODUCTION:

It has been known that aluminium-Silicon alloys are important wear resistance materials, they are mainly used in the internal combustion engines. Regarding the role of silicon and optimum content for the highest wear resistance , many controversy results have been reported. (1-2). Recently,a series of pure aluminium with a range of silicon content up to 20% have been investigated (3) and the reported results indicated that with increasing silicon content wear resistance is improved. Furthermore, it has been shown that certain alloying elements when added to the binary aluminium-Silicon will improve the seizure resistance of the materials (4) however, those elements may well reduce the cofficient of thermal expansion.

The present work stress on the role of alloying elements addition to the eutectic Al-Si binary system in order to characteris it wear behaviour and the optimum material condition for maximum wear resistance.

EXPERIMENTAL PROCEDURE:

The wear tests of the alloys are carried out on a pin-on-disc type machine. The disc is made of medium carbon steel with a carburized surface layer of 2 mm thickness and its hardness value _ 63RC. The sliding speed on the disc surface is kept constant for all the various loading tests conditions, at $\simeq$ 373 m/min. The wear rate is expressed as volume loss per unit sliding distance, in terms of Cm^3/cm. The wear tests are mainly carried as a function of loads for about 30 min, sliding time.

The alloys used in this investigation are made from commercial aluminium of purity 99.6% Al. Alloying addition are added in a form of master alloy and the nominal composition of the alloys is shown in table (1). The as-Cast alloys are annealed for a period of five hours at 500°C, some parts of the alloys are submitted to aging treatment at 130°C for five hours following the solution treatment at 500°C. The final specimen cross section is $\simeq$ 8 x 8 mm.

3. EXPERIMENTAL RESULTS:

3.1. AS-HOMOGENIZED ALLOYS:

The wear rates of the multicomponent aluminium-Silicon alloys A_1 , A_2 and A_3 are plotted in Fig.(1) against the applied loads at constant sliding speed. For all examined alloys, wear rates are observed to increase gradually with loads. The corresponding wear rates values are in the rang 10^{-10} - 10^{-8} $Cm^3.Cm^{-1}$, which is clearly falls in the region of "mild wear". In Fig. (1), a transition point is observed at 40 N bearing pressure, which could indicate that the mechanism of material removal during dry sliding contact is somewhat controlled by applied loads. On the other hand, Fig.(2) shows the effect of different copper content on the wear resistance of the alloys. The results suggest that with increasing copper content a relatively increases in the wear resistance are obtained, under various loading conditions. However, at high bearing applied load $\simeq$60N, the difference between the alloys resistance are reduced.

In order to evalute the improvement of the wear properties brought about by the basic elements addition Mn, Ni and Ti/B and the variable copper content, the eutectic Al-Si alloy is examined under the same conditions. The results of tests are presented in Fig.(3) and the observed wear rate of the eutectic alloy lies in the range of 10^{-7}-10^{-6} cm^3/cm at this relative high speed. Thought most ealier work has been carried out at lower sliding speed for the binary Al/Si alloys however, the present results compare reasonably with previous work (3). From the above results, it is possible to deduce that the improvement in the modified eutectic alloys are mainly due to the addition elements. it is to be noted, that heavy seizure is observed in the eutectic alloy above $\simeq$20N applied load.

It is generally observed that some of wear debris where adhered to the counterface disc, and the amount of deposited particles increases with loads as can be expected. On the other hand, the amount of transfer debris into the counterface is considerably high for the binary eutectic alloy compare to the alloyed materials.

3.2. AGGED ALLOYS:

The microhardness values of both aged and homogenized alloys are plotted in Fig.(4), where it is clear the effects of alloying addition on the strength of the binary eutectic system. After aging treatment a further increases in strength can also be observed, Fig.(4), and being a function of copper content in the alloys. Such effect is normally attributed to the present of the second phase precipitates, and it is likely to be of copper-aluminium base mainly.

From the results of wear tests for the aged alloys, Fig.(5) it is possible to conclude that the slight improvements which are obtained in wear resistance could only be due to aging treatment, however the range of wear rate did not change. Moreover, it is observe that in the case of aging, the wear rate is lower for the materials having the lower copper content, this is quite the contrary to the homogenized alloys behaviour.

4. DISCUSSION:

The types of wear observe generally in aluminium and some aluminium alloys are classified (3) into "oxidative and metallic". However, this classification in the case of binary aluminium-silicon materials are mainly related to certain wear rate values and it is not clear whether such values can be valid with changing the bearing loads values or the sliding speeds.

The different wear mechanisms such as delamination, adhesion and abrasion are likely to be operating simultaneously. Sarkar and Clark (5) indicated that for the binary Al/Si alloys, mutual transfer of materials between pin and disc is the main dominating mechanism. Furthermore, it has been indicated (6) that the possibility of stick-slip type of mechanism i.e. adhesion and abrasion, on the wear surface should be considered to explain the wear features for certain alloys. It is possible to argue that in the employed alloys the presence of silicon in the alloy is responsible for the brittleness and low strength, which can not sustain the high plastic strain and will cause the extensive surface and subsurface cracking. Moreover, mutual transfer and build up of layers on the pin surface is observed to occure in the present materials also, and a deposite surface layers are formed on the pin, which in turn will be delaminated under surface forces. Therefore, it is possible that both last mechanisms are operating simultaneously and respensible for wearing of the materials.

As indicated above, the presence of alloying elements improves the wear behaviour of the binary Al/Si and wear rates being loads dependent. Such dependent and existance of the transition point, Fig.(1), could be related to change in wear mechanism i.e. one of the acting mechanism is dominating. Furthermore, the transition could be as well related to a critical temperature at the contact surface. (7). However, under present tests conditions, the recorded temperature 2mm above the contact surface is about 30-40°C, therefore it is not likely that temperature will have a determing effects on the wear mechanisms.

The improvement in wear resistance for aged alloys could be due the presence of the second precipitates. It should

6

be indicated, that the relation between the material strength and its wear resistance is not straight forward relation (8), since precipitates could well enhance the nucleation of subsurface cracks (9). Therefore wear resistance is expected to drop with increasing the second phase precipitates, this is being the case of the present aged materials, i.e. the materials with higher copper content shows lower wear resistance.

CONCLUSION:

1. Wear resistance under various loads are improved for the eutectic Al/Si system by the alloying addition Cu, Mg, Ni and Ti/B, and the wear rates being loads dependent.

2. Mutual-transfer is being observed to occurs between the pin and disc surfaces.

3. Two simultaneously mechanisms are likely to be responsible for the materials removal from the pin surface.

4. After an aging treatment the low copper content alloys shows the highest wear resistance i.e.wear resistance has an inverse relation with precipitates density.

REFERENCES:

1. J. Clark and A.D. Sarkar, Wear, 54 (1979) 7.

2. G. Vandelli, Aluminio, 37 (1968) 121.

3. R.Shivanath, P.K. Sengupta and T.S.Eyra, Br.Foundaryman 70 (1977) 149.

4. A.J. Clogg and A.A. Das, Wear, 28 (1974) 353.

5. A.D. Sarkar and J. Clark, wear, 75 (1982) 71-85.

6. B N. Ptamila Bai, S.K. Biswas and N.N.Kumtekar, wear, 87 (1983) 237-249.

7. J.K. lancaster, Proc. roy. Soc. Ser A, 273,(1963) 466-483.

8. N.Saka, J.I.pamics-Teixeira and N.P. Suh, wear, 44 (1977) 77-86.

9. N.P.Suh, wear, 25 (1975). 111-124.

Table (1): Nominal Composition of Aluminium-Silicon Based Alloys.

Alloy designation	Si %	Cu %	Mg %	Ni %
A_0	11.5	-	-	-
A_1	11.5	1	1	1
A_2	11.5	2	1	1
A_3	11.5	3	1	1

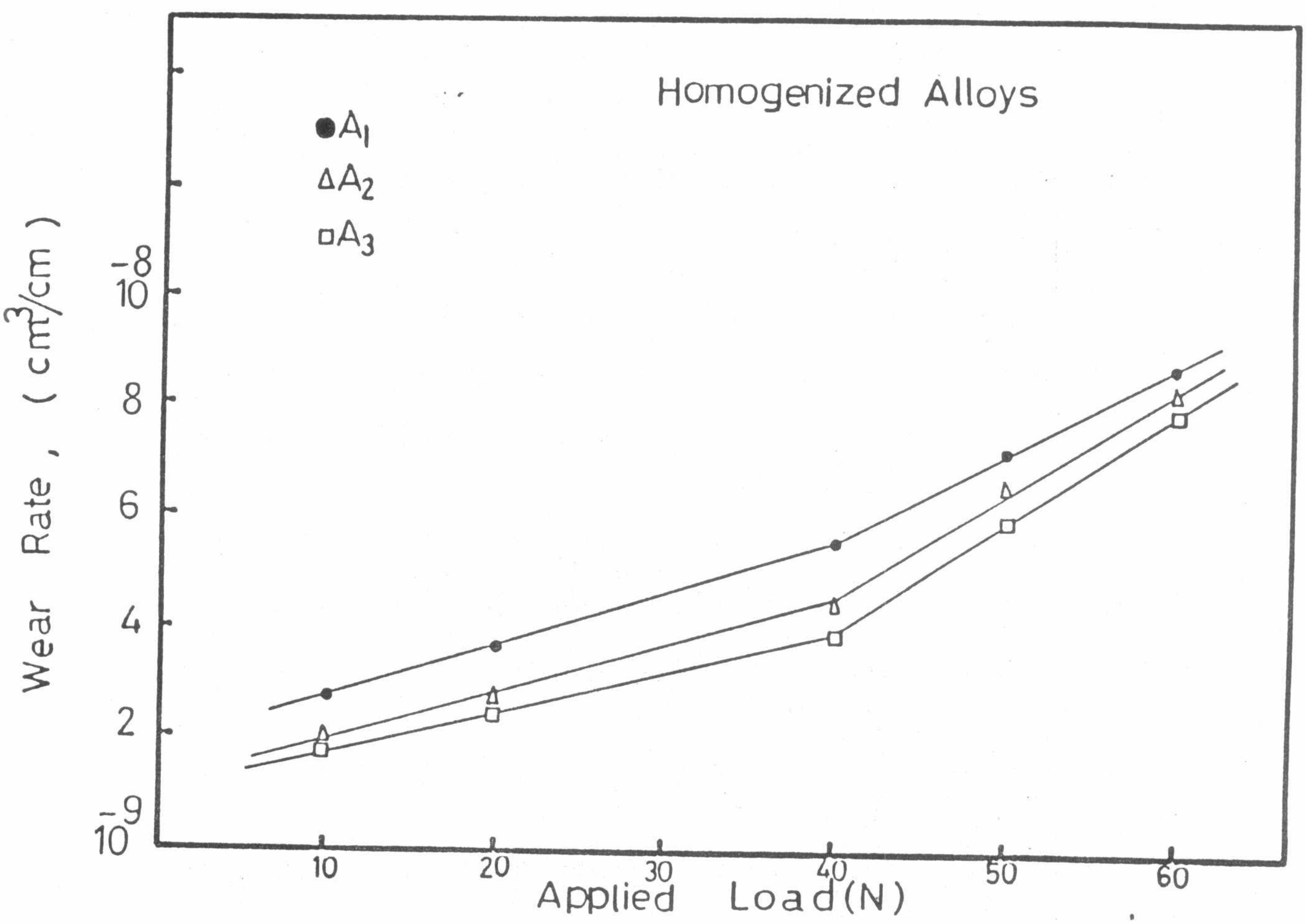

Figure 1. The changes in wear rate of alloys A_1, A_2 and A_3 as function of applied load.

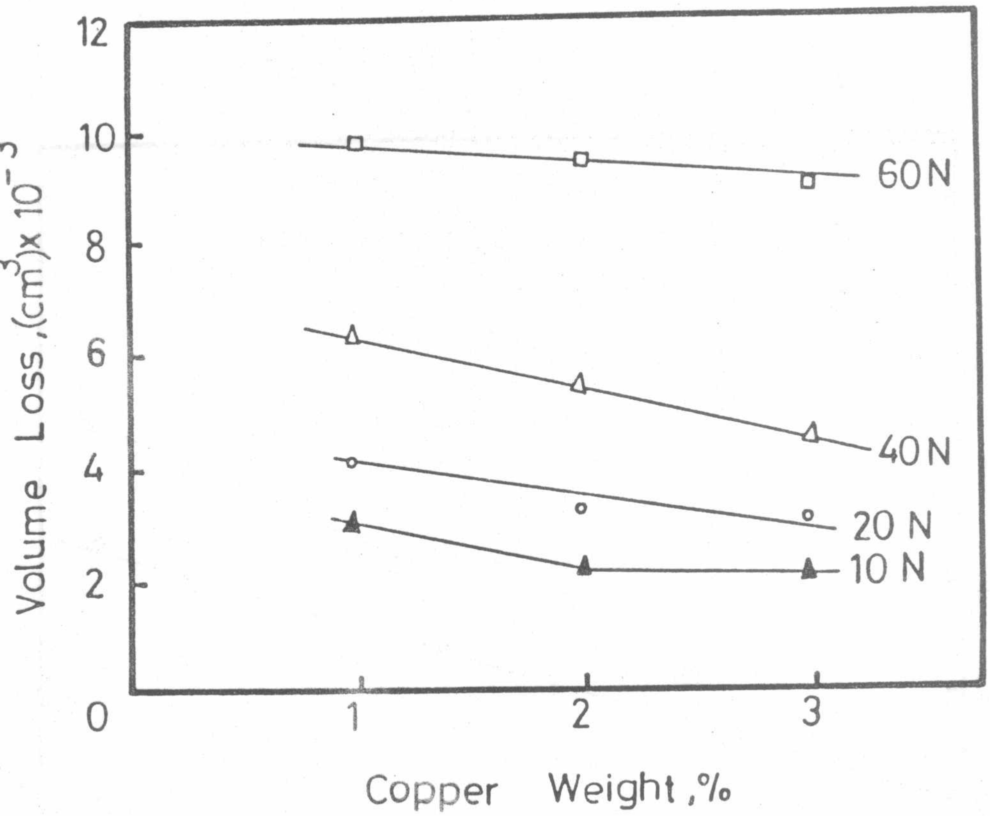

Figure 2. The effects of copper content on the wear behaviour.

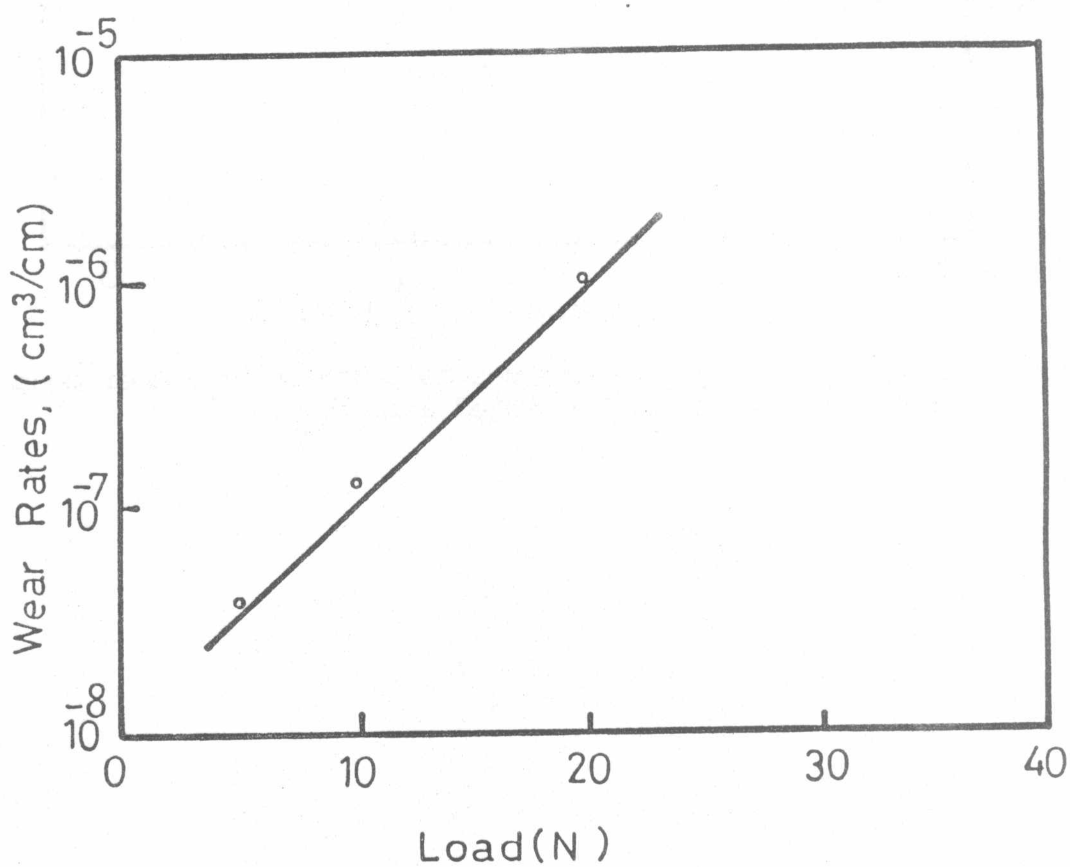

Figure 3. Shows the wear rates of the binary eutectic Al/Si alloys.

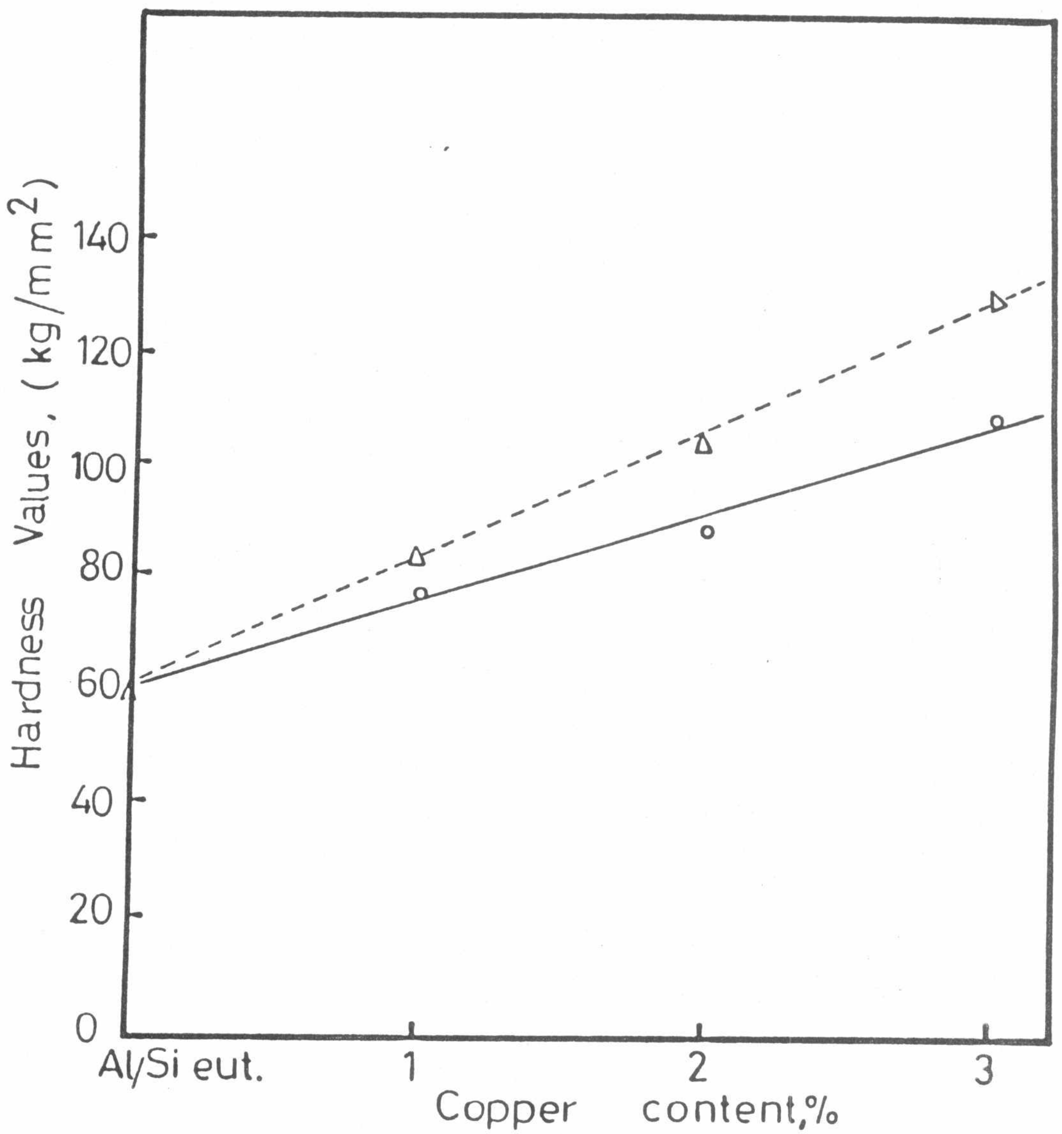

Figure 4. The changes of hardness values as function of copper content for the as-homogenized and aged alloys.

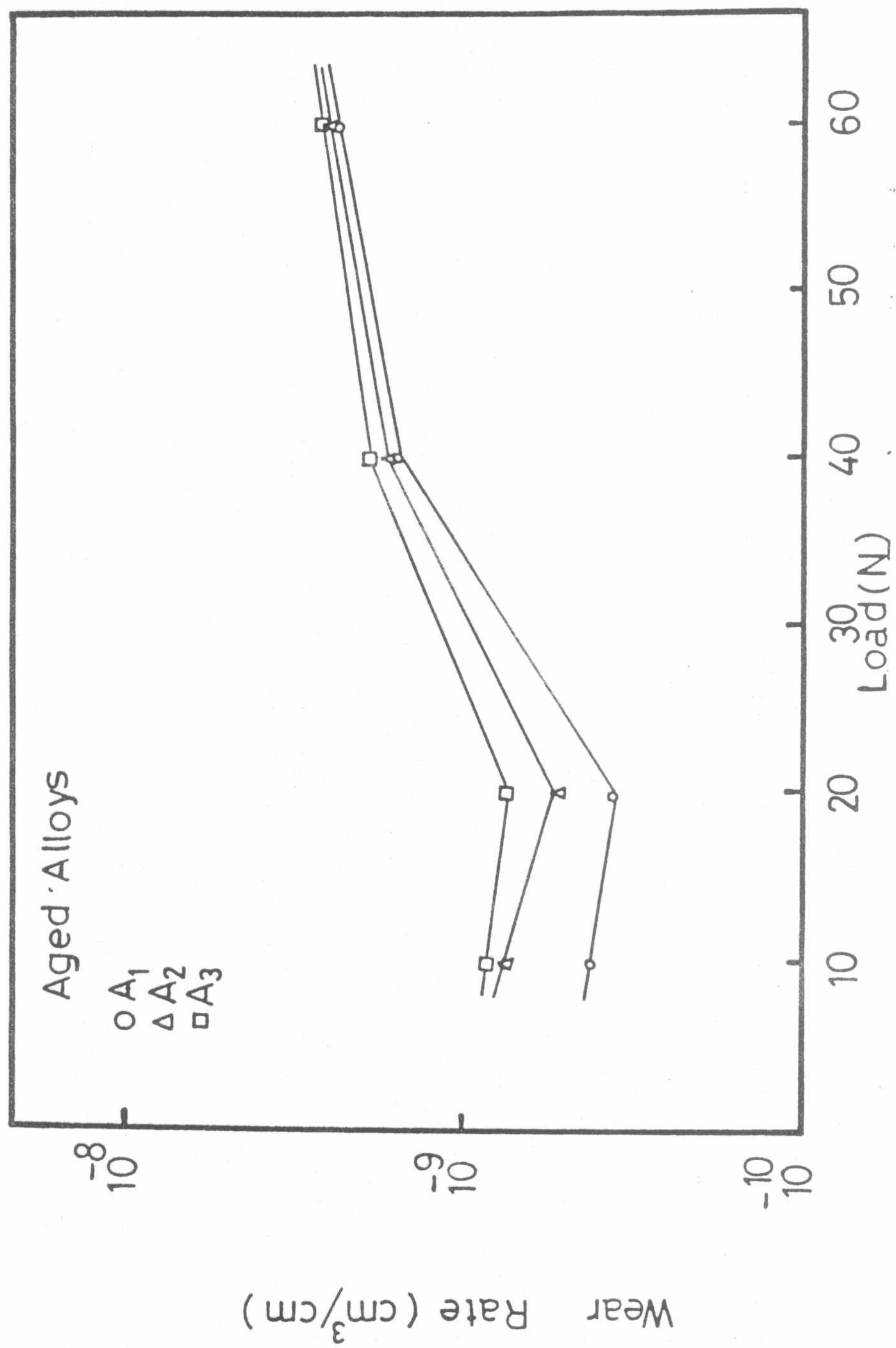

Figure 5. The changes in wear rate of aged alloys with applied loads.