friction and wearresistance) as much, that steels can be replaced in tribological systems.

Material and Experimental Procedure

Most aluminum cast alloys are based on binary aluminum silicon alloys. These elements form a eutectic system with its eutectic point at 11,7 wt% Si. Former investigation on simple laserremelting of aluminum silicon alloys showed, that due to rapid quenching an extended range of solid solution of silicon in aluminum associated with a displacement of the eutectic microstructure to higher silicon content is detectable. Therefore a hypereutectic alloy (e.g. AlSi 17) can freeze with a hypoeutectic structure after remelting. Additional hardness increases more than 100%. Nevertheless hardness is absolutely still low (up to 130 HV) insufficient for new applications to these alloys.
To increase hardness further either ceramic particles or mixtures of these ceramic particles with nickel powder (ratio of mixture: 67 wt% ceramic, 33 wt% Ni) are incorporated in-situ into the surface layer of AlSi 17 during laserremelting. Table I shows the choosen ceramics and their physical properties.

Table I. Ceramic Particles used

	Cr_3C_2	B_4C	SiC	TiC
Melting temperature [°C]	1890*	2450	2760*	3067
Hardness [HV]	2650	3700	2600	2800
Density [g/cm^3]	6,68	2,52	3,22	4,93

* Decomposition

As good mixing is aimed for, the specimens are preparated in a special way. Firstly saw cuts of 3 mm depth and different widths (0,6 mm, 0,9 mm) are put into the surfaces. Secondly these are filled with ceramic particles. The as-prepared specimens are remelted along the saw cuts whereby the liquid is heated up to the boiling point. Laserremelting is done with a Rofin-Sinar 5000 W CO_2-Laser, the parameters are listed in table II.

Table II. Parameters of Laser Treatment

Laserpower	Thrust	diameter (foc. beam)	Position of Focus	Focal length	diameter (mirror)
4,5 KW	60 mm/s	0,41 mm	+1 mm	200 mm	34 mm

The microstructures of the lasertracks are firstly analysed using light- and electron-microscopy, supported by EDX. Secondly hardness is determined (F_N = 100 N, t = 15 s). To probe the wear properties firstly the micromechanisms of abrasive wear are investigated using a metallographic scratching method [4]. The specimen is moved parallel and straight under a diamond pyramid, which is loaded with a force normally to the specimens surface. The plane becomes scratched showing three possible mechanisms of damage, namely microploughing, microcutting or microcracking. Ideal ploughing leads to

no disspation of matter, it is pressed aside by plastic deformation. If microcutting occurs, the material is separated by combined shearing and cracking. Brittle fracture is the dominating mechanismen for microcracking.
During sratching a frictional force results, which depends on the groove path. An abrasive coefficent of friction is defined as ratio of measured frictional force and applied load. The environment of the scratchgrooves is investigated by electron-microscopy.
Secondly the wear characteristics of the surface treated AlSi 17 alloy are examined. Grooving wear is investigated by a pin on disk test with Flint (80 mesh) grinding paper as counterpart. Sliding wear is also simulated in a pin on disk test but using 100Cr6-steel as counterpart. Additional investigations are carried out on cavitation erosion wherein surface fatigue is the dominating wear mechanism.

Experimental Results

Microstructure

The resulting lasertracks are more than 3 mm deep and more than 1 mm wide, and can be subdiveded into two areas, the central zone containing a mixture of ceramic and substrate and an outer zone containing only rapidly quenched aluminum silicon (Fig. 1). The best dispersion rate is achieved by adding B_4C (Fig. 2) or a mixture of B_4C and Nickel (Fig. 3) into the small saw cut. The resulting microstructures consist of small partly remelted ceramic particles, rapidly quenched aluminum-silicon and needle like phases. The content of B_4C-particles is about 30% in samples prepared with the smaler saw cut. The use of additional nickel suppresses the unremelted B_4C-content to about 25%. While Cr_3C_2 is completly decomposed SiC and TiC are melted only to a small amount. Depending on width of the saw cut, different microstructures can be fabricated in the central zone. Fig. 4 shows the resulting structure using the larger saw cut. Coarse particles are luted by

Figure 1. AlSi17+B_4C, lasertracks consisting of two areas: a central zone containing a mixture of ceramic and substrate and an outer zone without ceramics molten

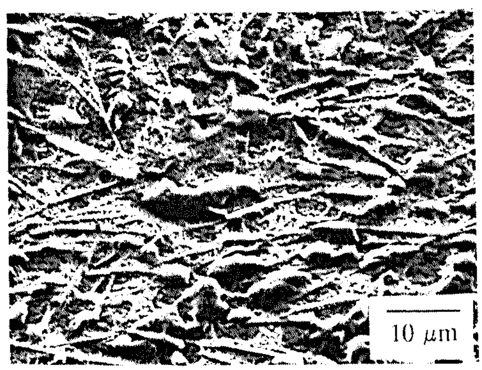

Figure 2. AlSi17+B_4C: See left track (Fig. 1) structure of the central zone: small partly remelted ceramic particles, rapidly quenched aluminum-silicon and needle like phases

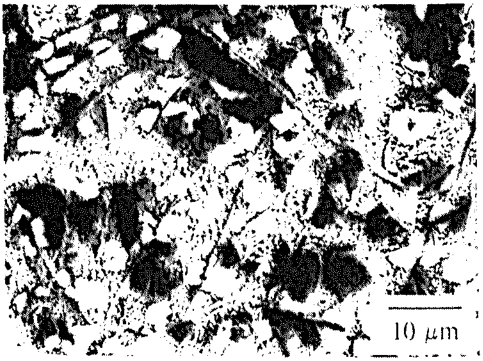

Figure 3. AlSi17+B_4C/Ni: Fine structure in the central zone. Due to the Ni addition a new phase occurs

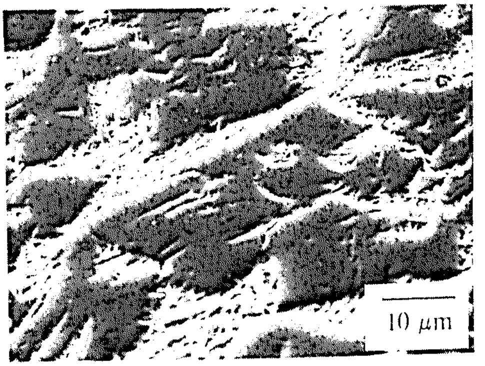

Figure 4. AlSi17+B_4C: See right track (Fig. 1): Cermet like structure in the central zone

rapidly quenched aluminum-silicon. This structure is well known from cermets and contains about 80% B_4C-particles.

Hardness and wear properties

The cermet like structure shows high hardness of about 900 HV_{10} when B_4C is added but combined with brittle behavior in scratch tests. A smaler saw cut leads to a better mixing of the different materials. Figure 5 shows the measured hardness obtained in central

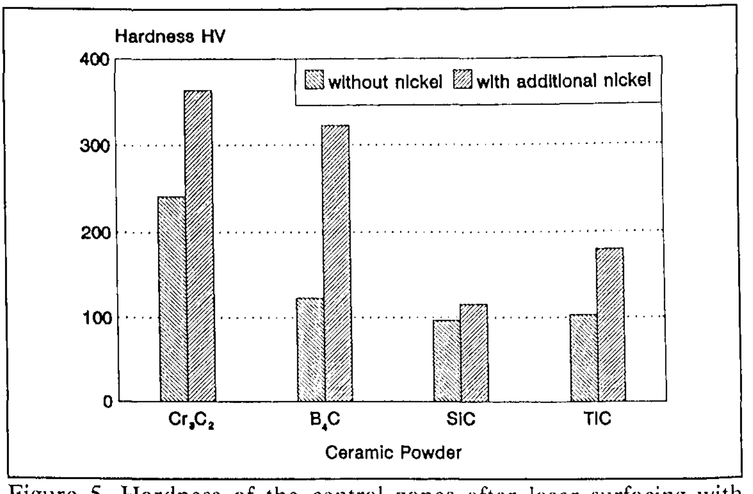

Figure 5. Hardness of the central zones after laser surfacing with different ceramics

zones of samples prepared with the smaler saw cut.
Scratchtests show, that good abrasive wear properties can be expected after alloying of B_4C or B_4C+Ni. Microcutting is the predominating wear mechanism with additional small amounts of microploughing and microcracking. Figure 6 shows a typical scratchgroove in AlSi 17 + B_4C. Rapidly quenched eutectic microstructure shows microcutting with small amounts of microploughing, needle like phases show pure microcutting while B_4C-particles are mostly pressed aside. Only a few particles crack during scratching.
Correspondingly these laser treated samples show good results in different wear tests. Especially a remarkable increase in wear resistance against abrasion (Fig. 7) and surface fatigue (Fig. 8) is conspicuous. Increase in sliding wear resistance is small.

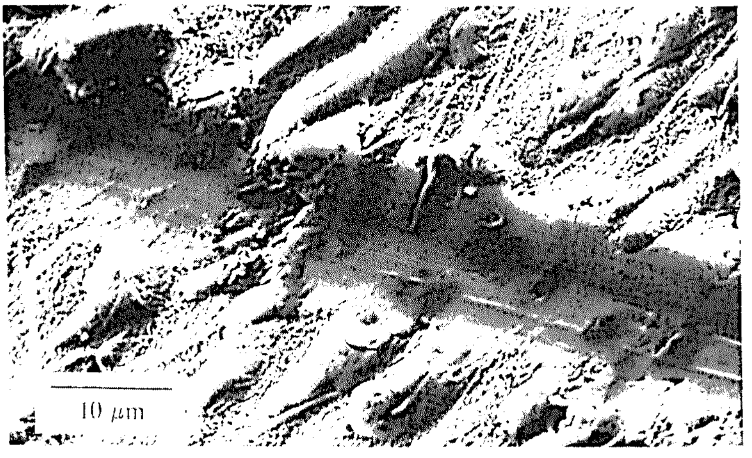

Figure 6. Scratchgroove in a central zone containing B_4C, microcutting predominates

Discussion and Conclusions

Microstructure

The remelting process can be subdivided into three stages: rapid heating of the material, rapid mixing and rapid solidification. Each stage contributes to the resulting microstructure.

Rapid heating. The laser provides an energy density which induces a raise in temperature to the melting temperatures in a period of time shorter than the hop time for diffusion at the final temperature. Consequently, no or very limited relaxation of the chemical composition has taken place, if this temperature is reached. Therefore the particular melting temperatures of the phases become valid and rule remelting in the outer zone (Fig. 9). In the central zone rapid heating is limited by the boiling temperature of aluminum (2467°C) and silicon (2350°C). According to the melting or decomposition

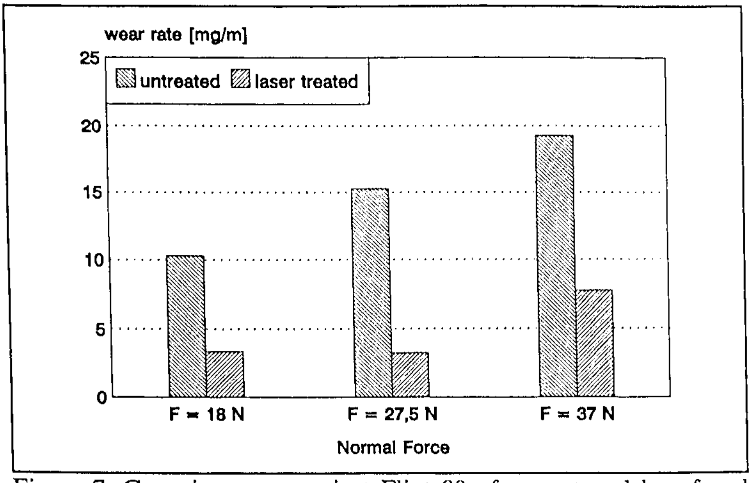

Figure 7. Grooving wear against Flint 80 of as cast and laserfused AlSi 17

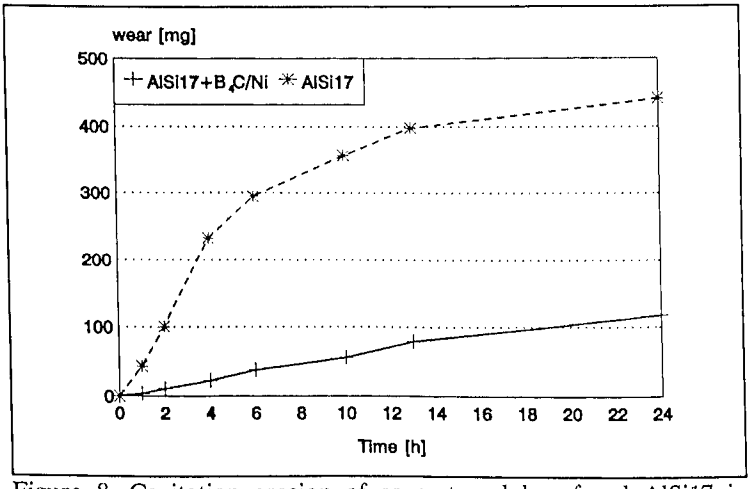

Figure 8. Cavitation erosion of as cast and laserfused AlSi17 in comparison

temperatures of the ceramic particles this leads to completely remelting of Cr_3C_2 and only partially melting of SiC and TiC. The melting temperature of B_4C is in the order of the boiling temperature of the substrate and therefore these particles are well dispersed.

Rapid mixing. Convection is the dominating mechanism for rapid mixing. The process is on one hand influenced by complete or incomplete melting and on the other hand by its duration. Zones of high alloy content in the adjacent liquid exist. Mixing takes place as

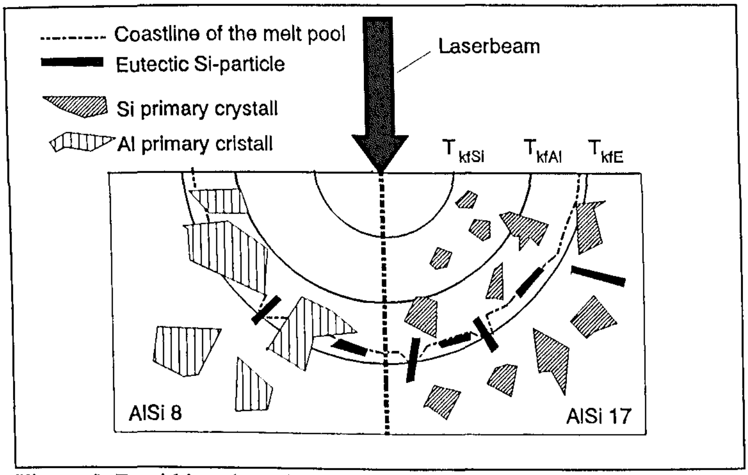

Figure 9. Rapid heating of multiphase material, schematic (e.g. Al-Si-alloy, left: hypoeutectic, right: hypereutectic). The melting temperatures (T_{kf}) of the different microstructure elements are important.

well in the liquid state as in the vaporous state.

Rapid solidification. As soon as the laser is moved away, the process of rapid solidification starts favored by excellent thermal conductivity of aluminum. As the melt has variable composition and temperature, the conditions are very complex. Heterogenous nucleation starts at undissolved particles and at the coastline of the unmelted substrate. Also homogenous nucleation may occur because of large undercooling.
As the new phases in the microstructure are too small to be analysed by EDX some suggestions are made on their composition. Although phase diagrams are not valid for rapid cooling these suggestions are based carefully on the related binary and ternary phase diagrams. In the ternary system Al-Si-C exist three ternary compounds [5]. Large needles are presumably Al_4SiC_4. The smaler ones are probably a very hard compound of aluminum and boron: AlB_{12}. If nickel is added very hard nickel-boron compounds may form additionally.
Furthermore an important observation is the change in morphology of eutectic microstructures, which solidify last. The new extremly fine net-structure should provide the desired mechanical surface properties. This structure results evidently from homogenous nucleation of supersaturated aluminum, which is immediately followed by crystallisation of one or two compounds from the residual liquid.

Mechanical and Tribological Properties

Investigations of hardness and wear properties of these resolidificated structures show that the surface properties of hardened steels are achieved if the larger saw cut is used. The raise in hardness is due to high content of B_4C particles. If the smaler saw cut is used

there is only little raise in hardness because hard particles are isolated in the matrix and cannot hinder plastic deformation. Additional hardening of the matrix by alloying of nickel is necessary.
As wear resistence is not only depending on hardness but also on local plasticity and fracture toughness, the suppresion of microcracking leads to a remarkable improvement in abrasive conditions. Brittle ceramic particles are so small, that necessary deformation can occur in the surrounding net-structure, which bears a small amount of plasticity. The increase in wear resitance against surface fatigue is due to the refined microstructure. Therefore in this case fusion of hard particles into the surface layer is not necessary. Simple remelting leads to comparable results.

Acknowledgement

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