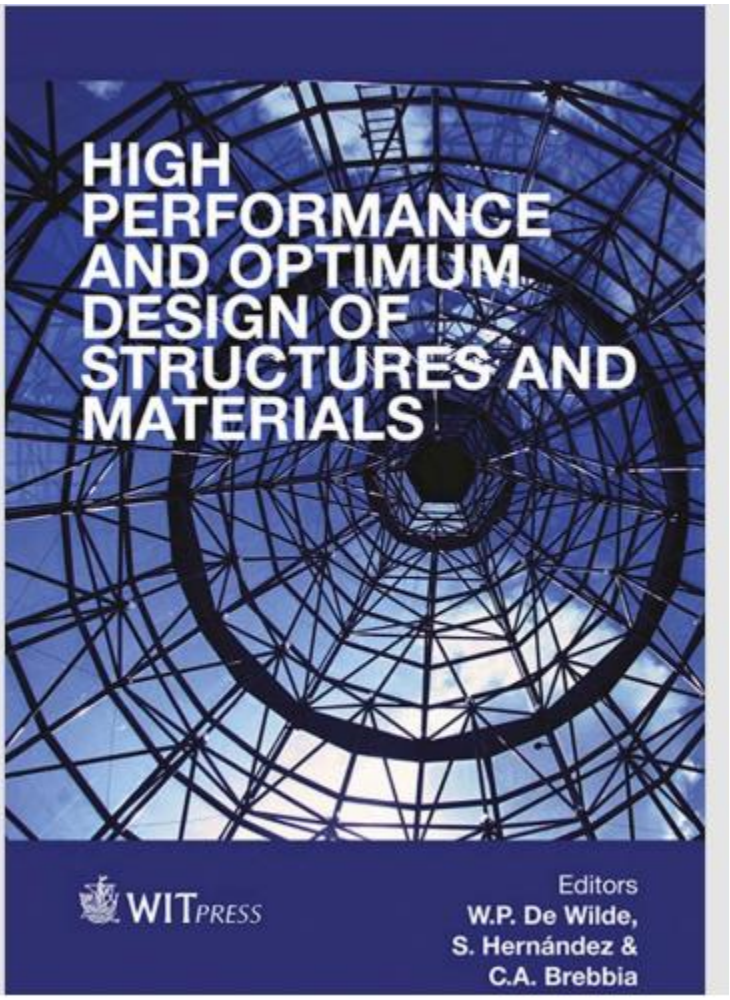

HIGH PERFORMANCE AND OPTIMUM DESIGN OF STRUCTURES AND MATERIALS
WITPRESS
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W.P. De Wilde,
S. Hernández &
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High Performance and Optimum Design of Structures and Materials

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Contents

Synergy between structural and architectural engineering:
the point of view of the structural engineer
L. Pyl, T. Tysmans, W. P. De Wilde, C. W. M. Sitters & H. Hendrickx.....1

Section 1: Material characterisation

Microstructural and mechanical characterization of magnesium based alloy MA14 (ZK60 A): evolution under deformation and heat treatment
E. F. Volkova.....17

Identification of material constitutive law constants using machining tests: a response surface methodology based approach
M. Daoud, W. Jomaa, J. F. Chatelain, A. Bouzid & V. Songmene.....25

Tracking heat-affected zone cracking susceptibility in standard and modified heat treated IN 738 superalloy welds
L. O. Osoba & M. O. H. Amuda.....37

The properties of innovated mortars utilizing secondary raw material
M. Čáchová, D. Koňáková, E. Vejmelkokvá, M. Keppert, P. Reiterman & R. Černý.....49

Effect of specimen size on cancellous bone microstructural parameters
K. Tanaka, S. Sezaki, S. Enoki & T. Katayama.....57

Prediction of roll separating force in a roll pass design of micro-alloyed steel rods
T. El-Bitar, M. El-Meligy & E. El-Shenawy.....67

Physicochemical characterization of modified multicomponent binder mortar in relation to calcium hydroxide leaching
N. Mohamed Sutan, I. Yakub, S. Hamdan & Z. A. Talib.....81

Selection of conductive yarns for knitting an electrical heating element
I. Šahta, I. Baltina, N. Truskovska, J. Blums & E. Deksnis 91

Physicochemical characterization of polymer composite cement systems
N. Mohamed Sutan, I. Yakub & S. Hamdan 103

Section 2: Experiments and numerical analyses

Numerical experiments for inverse analysis of material properties and size in functionally graded materials using the Artificial Bee Colony algorithm
H. Sakurai 115

Dynamic responses of a steel composite bridge subjected to a moving high speed train load in comparison with a PSC box girder bridge
S. Kim, H. Kim & J. Lee 127

Process development for 3D laser lithography
N. Kaste, A. Filbert, U. Mescheder, T. Rang & G. Rang 139

Effect of mesostructure on strain rate dependent behaviour in high strength steel sheets
K. Natori, R. Kishi, H. Shimahara, Y. Arao & T. Tanaka 151

The mitigation of the progressive collapse of a 9-storey structure incorporating United States Department of Defence guidelines
M. Izadifar, R. Naghshbandi, R. Abadi & Ir. A. Ahmad 163

Section 3: Composite materials and structures

The study of a CVT belt using the composite material of carbon fiber-reinforced thermoplastic resin
T. Minagawa, T. Tanaka, A. Yoshihiko, T. Ichiki & A. Inoue 177

The effect of the amount of process control agent on the properties of Cu25W composite powder
S. Biyik & M. Aydin 189

The high temperature resistance of a para-aramid fibre-reinforced concrete composite
D. Koňáková, M. Čáchová, K. Polozhiy, E. Vejmelková, M. Keppert & R. Černý 201

Reinforcing concrete shells with cement composite stay-in-place formwork: numerical analysis of a case study
E. Verwimp, T. Tysmans & M. Mollaert 213

Crashworthiness response of honeycomb metallic-GFRP energy absorption devices
L. Romera, J. Paz, M. Costas, J. Diaz & S. Hernández.....225

Section 4: Green composites
(Special session organised by H. Takagi & T. Katayama)

Heat transfer analyses of natural fibre composites
H. Takagi, A. N. Nakagaito & K. Liu.....237

Development of the fabrication process of carbon nanotube reinforced polylactide (PLA) nanofiber and evaluation of its mechanical properties
K. Tanaka, M. Hashimoto, M. Nagura & T. Katayama.....245

Proximity heating of CFRTP molding dies by using high-frequency direct current
K. Tanaka, R. Sue, K. Iwamoto & T. Katayama.....255

Section 5: Composites for automotive applications
(Special session organised by K. Takemura & K. Tanaka)

FEM analysis of the temperature distribution of CFRTP pipe mold with direct resistance heating
K. Tanaka, Y. Matsuura, R. Harada, T. Katayama & S. Enoki.....265

CFRTP molding method of the three-dimensional shape by using direct resistance heating to carbon fiber
S. Enoki, K. Moriito, K. Tanaka & T. Katayama.....273

Effect of the molecular weight of polycarbonate on the impact resistance of continuous carbon fiber reinforced polycarbonate composites
K. Tanaka, H. Koriyama, S. Isshiki, T. Katayama & M. Shinohara.....283

Evaluation of the interfacial and interlaminar shear strength of carbon fiber reinforced polycarbonate made by a unidirectional sheet
K. Tanaka, M. Suzue, S. Isshiki, M. Shinohara & T. Katayama.....291

The effect of crystallinity on the mechanical properties of plain woven carbon reinforced composites using polypropylene
H. Katogi & K. Takemura.....301

High-speed compression molding of continuous carbon fiber reinforced polypropylene
S. Enoki, K. Kojima, S. Mizuno, K. Katayama & K. Tanaka.....311

Formability evaluation of carbon fiber NCF by a non-contact 3D strain measurement system and the effects of blank folder force on its formability
K. Tanaka, R. Ushiyama, T. Katayama, S. Enoki & H. Sakamoto 317

The mode I interlaminar fracture toughness of carbon fiber/epoxy resin composite with freezing after water absorption
H. Katogi & K. Takemura 327

Section 6: Structural optimization

Optimization of steel penstock in a bored tunnel
S. Kravanja 337

Sustainable design using multiobjective optimization of high-strength concrete I-beams
T. García-Segura, V. Yepes & J. Alcalá 347

Seismic shakedown design of frames based on a probabilistic approach
S. Benfratello, L. Palizzolo & P. Tabbuso 359

Performance of surrogate models in reliability-based design optimization
M. Cid Montoya, J. Díaz & S. Hernández 371

Diagonalization strategies in search of structural optimization
M. T. Rodríguez-León & J. Sánchez 381

Some applications of reliability based design optimization in engineering structures
C. López, A. Baldomir & S. Hernández 393

Section 7: Optimization problems

The application of Differential Evolution to HVAC optimization
R. W. Derksen & H. Guenther 407

Atypical design optimisation of structures: case studies
A. Maheri 419

Predictive service life analysis of characteristic applications of zeolite concrete in building structures
V. Kočí, M. Jerman, J. Maděra & R. Černý 431

Modeling the thermal performance of passive roofing systems in a tropical climate
S. Tong & H. Li 443

Section 8: Steel structures

Compression characteristics of spheroidal graphite cast iron pipe members
T. Yamaguchi & Y. Kimura 455

Optimal design of through-truss steel bridges
C. Maraveas, A. Papagiannakis1, K. Miamis & K. Tasiouli 465

Section 9: Timber structures

Behaviour of creep of timber beams under natural environmental conditions
A. Brokans & L. Ozola 479

Insulating timber-framed walls of historical buildings using modern technologies and materials
M. Jarosz 491

Section 10: Corrosion problems

Accelerated corrosion tests of waste-gated turbocharger's adjustable and fixed end links
K. Wilton-Smith, Z. Khan, A. Saeed & M. Hadfield 501

Impact of the soil resistivity on IR drop when applying a cathodic protection system with galvanic anodes on PCCP
A. Mujezinović & A. Muharemović 509

Section 11: Surface modification

Effect of acid pretreatment of the plated substrate on the hardness of the carbon plating film formed by using a molten salt electrochemical process
K. Tanaka, Y. Okumura, H. Kurooka, T. Katayama, A. Yukawa & Y. Ueda 521

Improving the performance of magnesium alloys for automotive applications
R. O. Hussein & D. O. Northwood 531

The microstructure and wear behaviour of sintered Astaloy 85Mo
K. E. Öksüz, T. Gün & M. Şimşir 545

Microstructure and properties of NiCrBSiC overlay coatings deposited by the plasma scanning process
T. Simeonova, M. Tongov & G. Avdeev.....553

Effect of electric discharge machining of die steel DIN 1.2714 and DIN 1.2343 on surface characteristics and performance measures
M. A. Majid & A. M. Issa.....565

Bio-compatible polymer coatings using low temperature, atmospheric pressure plasma
S. Farhat, M. Gilliam, A. Zand & M. Rabago-Smith.....579

Polyaniline coated curauá fibres in polyamide-6 composites: the effect of fibre surface modification on the crystallographic properties
J. R. Araujo, C. B. Adamo, E. Robertis, A. Kuznetsov, B. Archanjo, C. A. Achete & M.-A. De Paoli.....589

Section 12: Innovative technologies

Insulation of flexible light emitting display for smart clothing
I. Parkova & A. Viļumsone.....603

Estimation of soil pore-water pressure variations using a thin plate spline basis function
M. R. Mustafa, R. B. Rezaur, M. H. Isa & H. Rahardjo.....615

Section 13: Heritage constructions

Advancing İznik tiles to the 21st century by applying nano structured materials
E. Gunay, M. Sariguzel & C. Imer.....627

Reduction in permeability of concrete, mortar and plasters by a chemical which retards water percolation and salt transfer
B. Sengupta & A. K. Chakraborty.....639

Section 14: Sustainable solutions

The effectiveness of sustainable floating structures in the Gulf Region (Middle East)
A. Ghafooripour, E. Nezamifar, O. Ogwuda & M. Sun.....653

Effect of silica aerogel on the thermal conductivity of cement paste for the construction of concrete buildings in sustainable cities
M. F. Khamidi, C. Glover, S. A. Farhan, N. H. A. Puad & M. F. Nuruddin.....665

Author index.....675

The microstructure and wear behaviour of sintered Astaloy 85Mo

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Abstract

Powder metallurgy enables cost effective production of powder metallurgy (PM) parts with complex geometries in automotive applications. PM materials are also extensively used for the production of components subjected to working conditions giving rise to sliding, rolling or abrasive wear, such as gears or cams. In this experimental study, Fe based pre-alloyed Astaloy 85Mo powder was used in the production of camshaft spur gear. The gas carburizing is carried out at 925°C for 3 hours. The camshaft spur gears were waited at 850°C for 1 hour to reach the required carbon concentration. Oil hardening is carried out at 82°C, soaking time is 30 min. The effect of gas carburizing on the microstructure, density, hardness and wear properties of Astaloy 85Mo+0.5% graphite was investigated. Furthermore, the microstructure characterization and worn surfaces of camshaft spur gear were examined using a high magnification optical microscope.
Keywords: powder metallurgy, Astoloy 85Mo, gas carburizing, wear.

1 Introduction

Demands on gear materials are continuously increasing. This is mainly because of developments in the automotive industry towards high performance vehicles with low fuel consumption and low environmental impact. A good example can be to look on car gear transmissions as very demanding ones. In the period from World War II to the present, their gear module decreased from between 4 and 5 mm down to between 2 to 3 mm, while effective torque transmitted increased nearly twice [1]. Powder metallurgy enables cost effective production of gears



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and parts with complex geometries. Besides that there are some advantages of P/M technique such as near net shape, green technique and almost no waste material. Surface quality is very important in production of a gear by P/M technique. In order to improve mechanical properties and surface quality of a gear, some methods are applied such as gear rolling for surface densification, heat treatment for hardness of P/M part and case hardening for improving surface hardness. Gear rolling is a well-known technology for improving the shape, surface densification and surface finish of steel gears [2–5]. Gas carburizing is a surface hardening method in which the surface of the components is saturated with carbon in a gaseous atmosphere containing carbon to accomplish this, the components are first heated in a neutral atmosphere to a predetermined temperature in the range of 870 to 940°C. The furnace is flooded with a suitable gas such as propane, butane or methane. Finally, the components are held at this temperature to allow for the diffusion of carbon into the case. After the carburizing treatment is completed, the components are quenched to obtain the required hardness, wear resistance and fatigue resistance on the surface, supported by a tougher core [6]. The mechanical behavior of sintered steels have been studied mainly by tensile and impact testing procedures [7]. However, the demand for components displaying an adequate resistance under heavy stress conditions, e.g. engine parts and transmission gears, has promoted considerable research efforts on PM components suitable to work under dynamic conditions. PM materials are also extensively used for the production of components subjected to working conditions giving rise to sliding, rolling or abrasive wear, as well as gears or cams. Therefore, a complete understanding of their tribological behavior is important. Several results on the dry sliding behavior of sintered ferrous alloys can be found in the literature [8–13]. In this paper, effect of gas carburization on microstructure and wear properties of hot pressed Astaloy 85Mo was investigated. Wear and micro hardness test were conducted and the mechanical properties were evaluated on the basis of microstructure.

2 Experimental procedure

2.1 Materials and method

The P/M steels were produced in an industrial plant using pre-alloyed Astoloy 85Mo (*Höganäs)* powders. A planetary gear with the gear data given in Table 1 was used in this study. Fig. 1 shows the camshaft spur gear configuration and Astaloy 85Mo with the compositions shown in Table 2 were used as base materials for the gears. PM camshaft spur gear has been manufactured by compaction of cylindrical blanks followed by sintering at 1130°C for 30 min in a mixture of 90% N_2 and 10% H_2 gas atmosphere by Sintek Powder Metallurgy Company. Carbon was added as ultra-fine natural graphite (UF4 graphite). Lubricant (*Intralube*® E) in proportion to 0.8 wt% was added to the powder-graphite mixtures.

Table 1: Gear geometry.

Number of teeth	Z	42
Normal module	mn	1.25
Major diameter	De	Ø55.80±0.05
Pitch diameter	Do	Ø53.28
Minor diameter	Di	Ø48.78 + 0 - 0.2
Depth of tooth type	hk	1.26
Tooth thickness	Sc	1.66±0.02
Grip angle	αo	17˚30'
Diameter with pin with two pins		Ø57.72±0.05
Max shimmy		0.03
Pin diameter	P18	Ø2.77

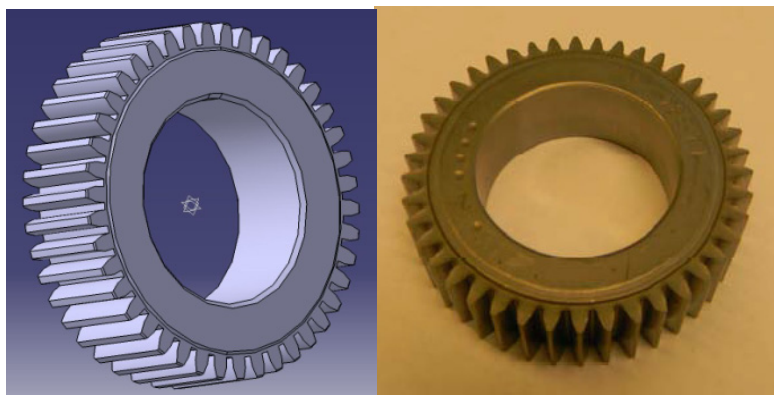


Figure 1: Configuration of the Astaloy 85Mo+0.5%C camshaft spur gear.

Table 2: Chemical composition of base powders (wt. %).

Gear	Material	Cu (%)	Ni (%)	Mo (%)	C (%)	S (%)
Camshaft spur gear	Astoloy 85Mo	0.04	0.04	0.85	0.48	0.005

2.2 Heat treatment

The gas carburizing was performed at 925°C for 3 hours. The camshaft spur gears were waited at 850°C for 1 hour to reach the %C concentration 0.72. Oil hardening is carried out at 82°C, soaking time is 30 min.

2.3 Mechanical tests

Vickers micro hardness values were measured under a load of 1 kg-f for each sample and microstructure of the gear was examined using high magnification optical microscope. For wear test, a pin-on-disc type apparatus was employed to evaluate the wear characteristics of samples. AISI 5190 steel disc having 65 HRc with 12 mm thick, and 160 mm diameter was used to serve as the adhesive medium. The pin specimens made from the samples were machined to approximately 5 mm in length. The pin was then mounted in a steel holder in the wear machine so that it was held firmly perpendicular to that of the flat surface of rotating counter disc. The samples were loaded against the abrasive medium with the help of a cantilever mechanism. Wear test was performed under varied loads such as; 20, 40 and 60 N and at a constant speed of 1 m/s and a constant sliding distance of 60 m with 80 mesh SiC paper for each sample. After the test, the wear pin was cleaned in acetone prior to and after the wear tests, and then dried after being weighed on a micro-balance with 0.1 mg sensitivity. Wear tests were carried out three times for three samples with and without gas carburized samples. Average of amount of weight loss was calculated and presented. Meanwhile confirmation tests were carried out at 60 N and at a constant speed of 1 m/s and a constant sliding distance of 150 m with 80 mesh SiC paper for each spur gear. After the confirmation test worn surface micrographs were taken using high magnification optical microscope.

3 Results and discussion

3.1 Microstructural analyses

Microstructure of the cam shaft spur gear was examined using high magnification optical microscope. After grinding and polishing, the samples were etched with solution of %2 Nital. Fig. 2 shows the microstructural aspects of the Astaloy 85Mo+0.5%C and gas-carburized Astaloy 85Mo+0.5%C samples.

Figure 2(a) shows the microstructure of the Astaloy 85Mo+0.5%C at sintering at 1130 °C for 30 min in a mixture of 90% N_2 and 10% H_2 gas atmosphere. It can be seen that the microstructure of sintered sample is ferritic. Figure 2(b) shows the microstructure in the gas-carburized Astaloy 85Mo+0.5%C spur gears. The microstructure is plate martensite that has high carbon content at the surface and in the core which is lath martensite with low carbon content.

3.2 Hardness and wear resistance

Micro-hardness was measured under 40x objective and an applied load of 1 kg-f using Vickers micro hardness tester. Five readings were taken and the hardness value has been reported in Figure 3. The blank density was 6.91–6.95 g/cm^3 range for the camshaft spur gear before the gas carburizing process and the

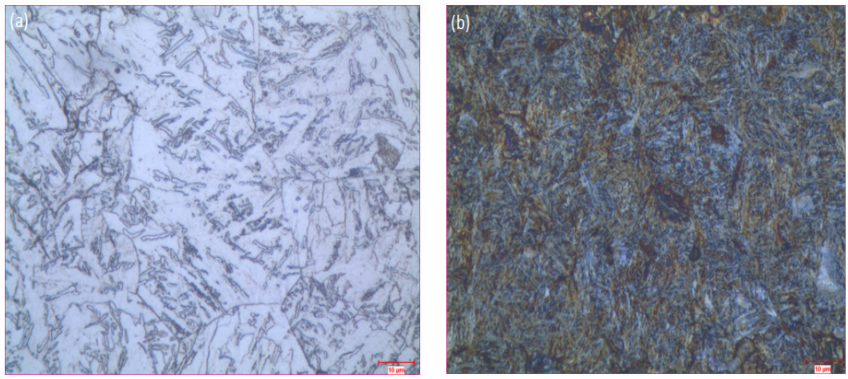


Figure 2: Microstructure photographs of (a) Astaloy 85Mo+0.5%C and (b) gas-carburized Astaloy 85Mo+0.5%C materials.

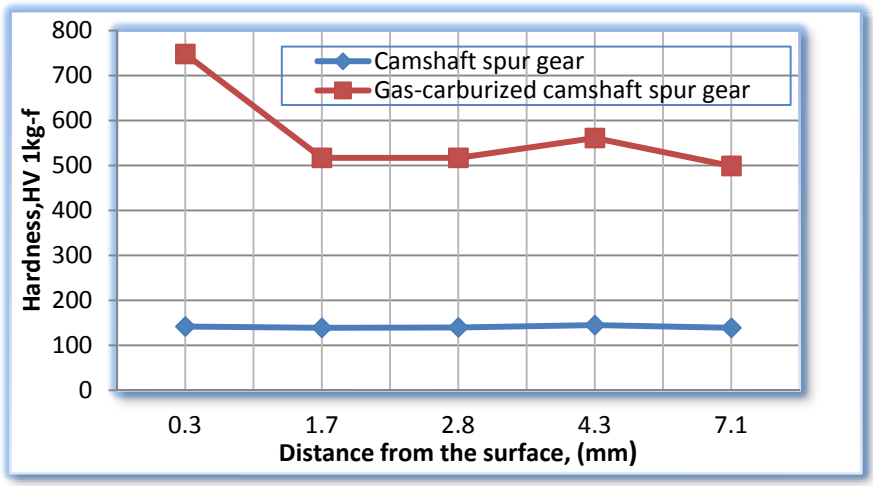


Figure 3: Micro-Hardness's for the Astaloy 85Mo+0.5%C and gas carburized Astaloy 85Mo+0.5%C spur gear.

surface micro hardness values is 142–139 HV in the range of 0.3–7.1 mm. After the gas carburizing process the blank density is 7.036–7.05 g/cm^3 range for the camshaft spur gear and the surface hardness is 748–499 HV in the range of 0.3–7.1 mm.

Fig. 4 shows the results of wear resistance for the the Astaloy 85Mo+0.5%C and gas carburized Astaloy 85Mo+0.5%C spur gear. The wear rate increased more or less linearly with increasing load for all tested samples. The wear rate was slightly higher for the Astaloy 85Mo+0.5%C spur gear due to decreased hardness and its microstructure.

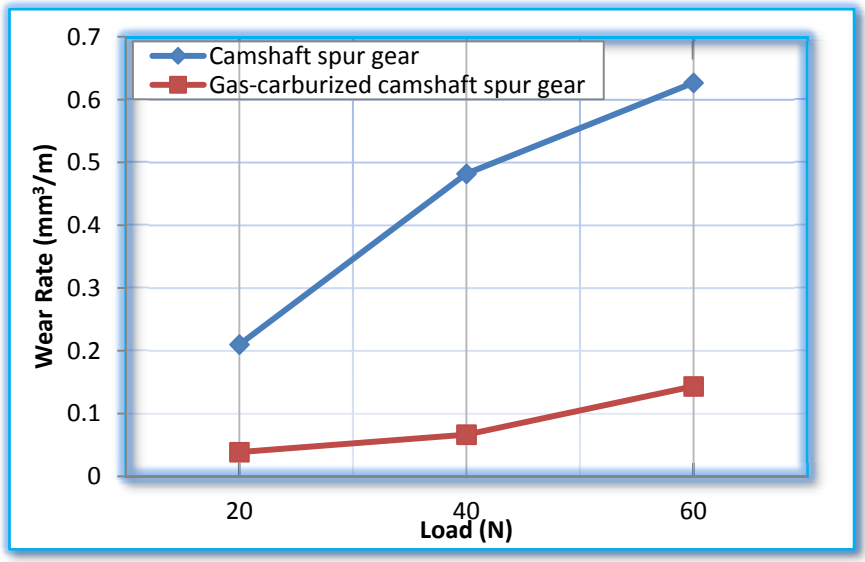


Figure 4: Results of wear resistance for the spur gears.

The worn surfaces, after tests carried out at 60 N, with SiC paper (abrasive size=201 μm) were characterized by the presence of fine and coarse grooves parallel to the sliding direction. Worn surfaces of the Astaloy 85Mo+0.5%C camshaft spur gear showing cracking of flakes along the wear track (marked arrow), diversion of wear grooves (Fig. 5(a)). Gas carburized Astaloy 85Mo+0.5%C camshaft spur gear showing abrasive traces, wear debris (marked arrow), material removal without delamination (Fig. 5(b)). Figure 5 shows the worn surfaces of the Astaloy 85Mo+0.5%C and gas carburized Astaloy 85Mo+0.5%C samples.

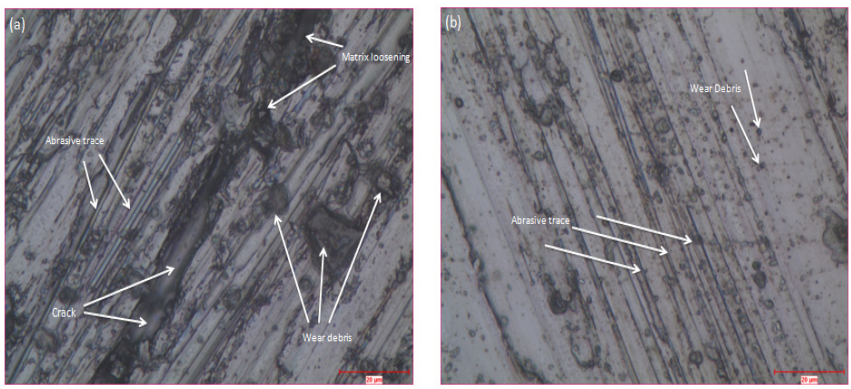


Figure 5: (a) Worn surfaces of the Astaloy 85Mo+0.5%C camshaft spur gear; (b) gas carburized Astaloy 85Mo+0.5%C camshaft spur gear.

4 Conclusions

The effect of gas carburizing on the microstructure, density, hardness and wear properties of Astaloy 85Mo+0.5% graphite were investigated. The following conclusions have been reached:

1-) It can be seen that the microstructure of sintered Astaloy 85Mo+0.5%C is ferritic and in gas carburized Astaloy 85Mo+0.5%C microstructure is plate martensite that has high carbon content at the surface and in the core which is lath martensite with low carbon content.

2-) For gas carburized Astaloy 85Mo+0.5%C, wear rate was very small, and wear rate was observed mainly as abrasive traces and wear debris. Gas carburized spur gear exhibit lower wear rate than the un-heat treated spur gear due to increased hardness and its microstructure. The weight loss of gears under 60 N applied load was measured as 0.1433 mm^3/m g for gas carburized Astaloy 85Mo+0.5%C and that is 4.374 times greater than that of gears without gas carburized gears.

3-) Gas carburized Astaloy 85Mo+0.5%C is suitable for gear production in automotive applications.

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