Materials & Science in Sports Technical Program

Introduction

Monday AM Room: St. Tropez Ballroom Salon C
April 23, 2001 Location: Coronado Island Marriott Resort

Session Chair: S. Haake

9:45 AM Opening Address

10:00 AM Keynote
Materials and Science in Sports–An Overview: *F. H. Froes*[1]; S. Haake[2]; [1]University of Idaho, Inst. for Mats. & Adv. Proc., Mines Bldg., Rm. 321, Moscow, ID 83844-3026 USA; [2]The University of Sheffield, Dept. of Mech. Eng., Sports Eng. Rsch. Grp., Mappin St., Sheffield S1 3JD UK

The major impact that advanced materials and innovative designs have made on sporting performance will be reviewed. Examples will be given from various sports including tennis, running, pole vaulting, golf, cycling and other sporting events.

11:00 AM Break

Materials in Sports I

Monday AM Room: St. Tropez Ballroom Salon C
April 23, 2001 Location: Coronado Island Marriott Resort

Session Chair: S. Haake

11:30 AM
Materials in Ski Design and Development: *Hugh Casey*[1]; [1]Office of Naval Research, Iterntl. Field Office, 223 Old Marylebone Rd., London NW1 5TH UK

This presentation proposes that the materials used in today's skis can be linked to specific performance criteria and trends in design, which have paralleled the transition from traditional to contemporary skiing technique. Performance is now the single most important issue determining the materials used, whether the intent is to produce a competitive ski for the racer or advanced recreational skier or an 'easy to use' ski for the novice or intermediate level skier. Advanced materials including lightweight metal alloys, carbon fiber composites, Kevlar, and even piezo-ceramics have been identified as performance enhancement factors. The author combines a science & engineering background with many years of ski instructing experience to review the contributions of materials in ski design and development.

12:00 PM
Advanced Materials for Recreational Applications: *Jim Withers*[1]; S. Pickard[1]; J. K. Kim[1]; R. O. Loutfy[1]; [1]MER Corporation

Advanced or engineered materials are enabling to many advances in a variety of technologies from electronic to structural and medical. Recreational or sports utilization of these advanced-engineered materials can benefit significantly. Examples are graphite fiber reinforced polymer tennis rackets and golf club shafts, bats and hockey or La Crosse sticks, tungsten weighted golf clubs, metal matrix composite inserts and glassy metal inserts to golf clubs.

Design and Development I

Monday PM Room: St. Tropez Ballroom Salon C
April 23, 2001 Location: Coronado Island Marriott Resort

Session Chair: F. H. Froes

2:00 PM
Superelastic Magnesium Alloys for Sporting and Leisure Applications: *J. C. Tan*[1]; M. J. Tan[1]; [1]Nanyang Technological University, Sch. of Mech. & Prod. Eng., Nanyang Ave., 639798 Singapore

Magnesium with a density of merely 1.74 g/cm3 forms the lightest structural alloys that are currently available for engineering applications. Therefore, the greatest advantage of choosing magnesium alloys for engineering design lies in its low density, which translates into higher specific strength and stiffness. The high specific properties could contribute considerably to the aspect of weight savings in the design and construction of sporting equipments. Besides being lightweight, Mg also has high torsion strain resistance and toughness. These attractive properties are highly sought after in various sporting and leisure equipments such as golf clubs, rackets, racing bikes, vaulting poles etc. However, unlike many other materials, wrought magnesium alloys exhibit poor formability at room temperature hence limiting its wide usage. The current research is aimed at improving the formability of rolled magnesium alloy sheets so that intricate shapes can be formed. It has been found that the ductility of wrought AZ31 (Mg-3Al-1Zn) alloy can be significantly improved by deforming it under superplastic state instead of resorting to conventional hot forming techniques. In general, AZ31 attains greater elongation at higher temperature and lower strain rates. The optimum conditions were found to be at 450°C and 2¥10-4s-1 which are capable of attaining a maximum elongation of 275%. The flow stress was observed to be highly dependent upon the strain rate which is a characteristic of superplastic material. The transition of m-values observed at temperatures below 500°C and at true strain rates of greater than 1¥10-3s-1 was suggested to be the result of the breakaway of dislocations from their solute atom atmospheres. The true flow stresses were almost constant during deformation with small amount of hardening attributed to dynamic grain growth. The average m-value of 0.33, elongation of about 250~300% and the coarse grain structure suggest that AZ31 can be classified as Class-I solid solution material. The extensive forming capability demonstrated by AZ31 sheets sheds new light on the potential of using this material for various sporting and leisure equipments so that its attractive mechanical properties can be fully exploited.

2:30 PM
High Performance Artificial Limbs for Paralympic Sports: *Oliver Gutfleisch*[1]; M. Jenkins[2]; [1]IFW Dresden, Inst. of Metallic Mats., PO Box 270016, Dresden D-01171 Germany; [2]University of Birmingham, Sch. of Metall. & Matls., Birmingham B15 2TT UK

Advances in materials technology are not only a prerequisite for top performances in almost any sport but have also revolutionized the performance levels in disabled sports as it now will be demonstrated at the Paralympic Games 2000 in Sydney. Besides the talent and determination of the athlete, it is the use of high performance artificial limbs which enable such astonishing results such as 11 seconds for the 100m sprint for below-knee amputees. This paper introduces the various components of such a device consisting of a soft liner made from silicone covering the stump and providing skin-compatibility, elasticity, tear strength and pressure redistribution. A woven carbon fibre composite is used for the hard socket on which a titanium adapter is mounted to provide the link to a carbon fibre unit replacing tibia and foot. The resulting structure exhibits high strength and stiffness together with relatively low mass. Varying the degree of fibre orientation in the foot unit will vary the bending stiffness which then can be tailored to ensure that the loading is elastic and that energy storage can be maximized. New exciting developments in advanced prosthetic devices also include the use of magnetorheological (MR) fluids as a damper in a knee joint resulting in a more natural gait and an automatic adaptation to different walking conditions. A microprocessor-based controller determines the current needed to be applied to the MR fluid damper to reversibly change its rheological behavior within milliseconds. A real-time gait control adapts to walking speed and allows the above-knee amputee to climb stairs.

3:00 PM

Geometric Profiles of Selected Brands of Ice Hockey Boots, Bladeholders and Blades: *Kelly L. Lockwood*[1]; Sean Reader[1]; Brent Dalrymple[1]; [1]University of Regina, Fac. of Kinesiology & Health Studies, 3737 Wascana Pkwy., Regina, Saskatchewan S4S 0A2 Canada

Customization of the design of hockey boots, bladeholders, and blades has been driven primarily by the technical demands of the sport of ice hockey. Skate manufacturers and skaters, in particular, believe that unique differences in design significantly contribute to enhanced skating performance. The purpose of this study was to geometrically profile seven brands of ice hockey boots, bladeholders, and blades in order to determine if significant differences in design do indeed exist. Thirty-two geometric measures per skate brand were obtained and a median was computed for each measure. Subsequently, the number of geometric measures above the median were then computed for each skate brand. A Chi Square Goodness of Fit test (df=6) revealed no significant differences between the seven skate brands ($p>0.05$). From a practical standpoint however, the geometric measures with the greatest variance between brands were the angle of the ankle and the manufacturer contour.

3:30 PM Break

Dynamics I

Monday PM Room: St. Tropez Ballroom Salon C
April 23, 2001 Location: Coronado Island Marriott Resort

Session Chair: M. J. Tan

4:00 PM

Dynamic Characteristic of Golf Ball Materials at Impact: *Kiyoto Maruoka*[1]; Noritoshi Nakagawa[2]; Yasuhisa Sekiguchi[2]; Kaname Yamada[1]; Seigou Sakagami[1]; [1]Sumitomo Rubber Industries, Ltd., Sports Goods Rsch. Dept. R & D, 2-1-1 Tsutsui-Cho, Chuo-Ku, Kobe, Hyogo 651-0071 Japan; [2]Hiroshima University, Faculty of Eng., 4-1 Kagamiyama 1 Chome, Higashi-Hiroshima, Hiroshima 739-8527 Japan

Golf balls are made of various visco-elastic materials as polybutadiene rubber, ionomer resin and etc. Visco-elastic spectrometer is useful to evaluate the visco-elastic properties of polymer materials. However, visco-elastic spectrometer can not evaluate the properties of golf ball materials at impact, because a golf ball at impact has too large deformation and too high strain rate for visco-elastic spectrometer. On the other hand, the split Hopkinson pressure bar is used to evaluate impact properties. However, this split Hopkinson pressure bar is for metal, this is not suitable for evaluation of the properties of polymer materials at impact. This cause is interference of propagated wave and noise. Dr. Nakagawa et al. modified the split Hopkinson pressure bar in order to be suitable for polymer materials. Author evaluated the properties of golf ball materials at impact based on the concept of the split Hopkinson pressure bar modified by Dr. Nakagawa.

4:30 PM

Analysis of the Characteristics of Fishing Rods Based on the Large-Deformation Theory: *Atsumi Ohtsuki*[1]; [1]Meijo University, Mech. Eng., 1-501 Shiogamaguchi, Tempaku-ku, Nagoya, Aichi 468-8502 Japan

There are very few scientific studies about fishing rods in the field of so-called sports-leisure. This study deals with large deformation of fishing rods that would be useful to develop a characteristic design of fishing rods. In this report based on the large deformation theory, the new fundamental equations can be obtained for thin, straight tapered fishing rods with circular cross-section under concentrated loads at free end. As a result, it is found that the large deformations of fishing rods can be described with dimensionless load parameters, ratios of diameter and supporting angles, respectively. Furthermore, the experimental verification of this analysis is carried out using a flexible rod model. The theoretically predicted results are in fairly good agreement with the experimental data. Consequently, the new theory proves to be of practical use.

5:00 PM

Snowboard Natural Frequencies and Damping Ratios: *Keith W. Buffinton*[1]; Steven B. Shooter[1]; Ira J. Thorpe[1]; Jason J. Krywicki[1]; [1]Bucknell University, Dept. of Mech. Eng., Lewisburg, PA 17837 USA

Stiffness and damping are widely acknowledged in the ski industry to be directly linked to performance. While many studies document the natural frequencies and damping ratios of skis, similar information for snowboards is unavailable. The present study measured the bending and torsional natural frequencies and model damping ratios for eight snowboards from two manufacturers. Natural frequencies and damping ratios were obtained for the first three bending modes and first two torsional modes. Quantitative results correlate well with qualitative descriptions offered by manufacturers and riders. Medium quality boards designed for beginner riders and characterized as “soft” have lower natural frequencies and larger damping ratios than similar boards designed for advanced riders and characterized as “stiff.” Moreover, boards designed for advanced riders and characterized as “high quality” have natural frequencies similar to “medium quality” boards but exhibit significantly larger damping ratios.

Dynamics II

Tuesday AM Room: St. Tropez Ballroom Salon C
April 24, 2001 Location: Coronado Island Marriott Resort

Session Chair: K. Prisbrey

9:00 AM Keynote
Sportsball Aerodynamics: Effects of Velocity, Spin and Surface Roughness: *Rabindra D. Mehta*[1]; Jani M. Pallis[2]; [1]NASA Ames Research Center, Mail Stop 260-1, Fluid Mech. Lab., Moffett Field, CA 94035-1000 USA; [2]Cislunar Aerospace Inc., San Francisco, CA USA

A significant amount of research has been conducted on sportsball aerodynamics since the last review article by Mehta (1985). The aerodynamics of several sportsballs (including baseballs, golf, tennis, cricket, volley and soccer balls) and the effects of surface roughness, velocity, and spin on the critical Reynolds Number are explained, compared and contrasted, supported by wind tunnel measurements and analysis. Most ball games are played in the Reynolds Number range of 50,000 - 300,000. Small disturbances on the ball's surface, such as the stitching on baseballs and cricket balls and the felt on tennis balls, affect boundary layer transition from a laminar to a turbulent state in this Reynolds Number range. For spinning balls, the Magnus effect, responsible for producing the lift force, is discussed in detail. Recent flow visualization studies by the authors and examples of the Magnus effect in action on the playing field are presented.

10:00 AM
Shock Absorbing Effectiveness of Hockey Helmet Liner Foams After Exposure to Repeated Impacts: *Evangelos Spyrou*[1]; T. Blaine Hoshizaki[1]; [1]Sport Maska Inc., R&D, 600 Boul. Industriel, St-Jean, Quebec J3B 1S7 Canada

The ice hockey helmet is considered a multiple impact device due to the nature of the game and the prolonged use of helmets by players. The liner foam is one of the many variables that influence impact absorption of a helmet. The purpose of this study will be to investigate how liner foams, used in hockey helmets, perform following exposure to repeated impacts. Foam samples will be of two types (vinyl nitrile and expanded polypropylene), two densities (4 and 6 pcf), and will measure 4x4" and 1/2" thick. Each sample will be impacted twenty times at two different levels of energy using a monorail drop test. Such information can be very useful in the design of helmets and possibly help prevent injuries.

10:30 AM
The Radius XR: Superior Equestrian Protective Headgear Technology: *Richard M. Timms*[1]; J. Montello[1]; M. Yokota[1]; D. Piper[1]; [1]Troxel

Troxel has developed the "Radius XR" helmet for protection during aggressive equestrian activities. Certain forms of equitation lead to a high rate of injury and death. In the past 2 years 14 "eventor" type riders have been killed in Europe and USA. Troxel will present a brief summary of high risk riding and its injury data. The Radius XR uses classical expanded polystyrene foam (EPS). Its uniqueness lies in combining the first external carbon fiber shell and an internal carbon fiber ring co-molded inside its EPS foam liner. These two features result in a light weight riding hat with: a) 2-3 fold increase in hoop strength over certified or uncertified "huntcaps"; b) ASTM/SEI certification level impact absorbing properties. The Radius XR uniquely serves to protect the rider from falls while riding a horse and from most crushing forces created by the horse.

11:00 AM Break

Materials in Sport II

Tuesday AM Room: St. Tropez Ballroom Salon C
April 24, 2001 Location: Coronado Island Marriott Resort

Session Chair: Kelly Lockwood

11:30 AM
The Effect of Golf Club Shaft Stiffness on Performance Variables–Implications for Club-Fitting: *E. S. Wallace*[1]; J. Hubbell[2]; [1]University of Ulster, Sch. of Applied Medical Sci. & Sports Studies, Shore Rd., Newtownabbey, Co Antrim BT37 0QB Northern Ireland; [2]United States Golf Association, Far Hills, NJ 07931 USA

The process of matching clubs with appropriate shafts to individual players is largely one of trial and error. Bending stiffness or shaft flex, mass, damping, torsional stiffness, and bend point are widely accepted as being the five main shaft properties that affect performance in golf. Considerable debate surrounds the individual and combined dynamic influence of these factors during the golf swing. The aim of this paper was to examine the effects of 5-iron clubs with shafts of different bending stiffness on selected golf performance measures. A laboratory-based experimental approach was used in the study. Eighty-four right-handed male amateur golfers gave their informed consent and participated in this investigation. Anthropometric and physical fitness measures were obtained for each subject and used in correlational analyses with shot performance measures. Objective measurements of the stance/set-up and swing kinematics along with clubhead presentation variables were obtained for each of the golfers during swings for each of three experimental clubs. A visual inspection of body kinematics data revealed differences in shaft stiffness had no observable effect within a given subject, although obvious and expected differences were noted between subjects. While statistically significant differences were noted among shaft types for clubhead speed, solid hit factor and ball/clubhead impact location, the actual magnitudes of these differences were considered negligible. No significant differences were noted for any of the postural variables at address due to shaft stiffness. These scientific findings lend support to conventional wisdom that shaft bending stiffness is perhaps most relevant to 'feel' of the golf club. However, the present study did not take into account other important launch conditions of the ball such as launch angle and spin rate.

12:00 PM
Is the Use of Advanced Materials in Sports Equipment Ethical?: *K. Prisbrey*[1]; F. H. Froes[2]; [1]University of Idaho, Mats., Metall. and Mining Dept., Moscow, ID 83844-3024 USA; [2]University of Idaho, Inst. for Mats. & Adv. Proc., Mines Bldg., Rm. 321, Moscow, ID 83844-3026 USA

The performance levels of athletes in various sports have shown dramatic improvements over the years. This improvement has come both from better trained (mentally and physically) athletes and also from improved equipment. This paper will discuss the ethical issues surrounding the use of advanced materials and design in this equipment. Comparison of improvements in performance in various human sports will be made, and contrasts drawn with equine events.

12:30 PM
Titanium in the Modern Automobile: *K. Faller*[1]; F. H. Froes[2]; [1]International Automotive Applications, TIMET Corporate Dev., Hemlock Rd., Morgantown, PA 19543 USA; [2]University of Idaho, Inst. for Mats. & Adv. Proc., Mines Bldg., Rm. 321B, Moscow, ID 83844-3026 USA

Because of its high strength and low density, combined with a low modulus, titanium offers many attractions for use in automobile appli-

cations. However, to date, use has mainly been in the sporting arena where price is not a major barrier. This paper will discuss racing car applications of titanium and very recent developments in which cost effective techniques have been used to produce titanium components for use in the family automobile.

Design and Development II

Tuesday PM Room: St. Tropez Ballroom Salon C
April 24, 2001 Location: Coronado Island Marriott Resort

Session Chair: Mike Jenkins

2:00 PM
Design of Foam Padding for Rugby Posts: *G. Lyn*[1]; N. J. Mills[1]; [1]University of Birmingham, Sch. of Metall. & Mats., Edgbaston, Birmingham B15 2TT UK

Rugby football goal posts are padded with polyurethane (PU) foam to guard against head injuries. There are no standards for such padding. The paper investigates the performance of such pads both experimentally, using an instrumented headform, and by Finite Element Analysis, with the foam modelled as a hyperelastic compressible material. The remoulded PU foam has a different response to the virgin material; the recycled foam varies in modulus, and some regions are compressed prior in the unloaded foam. The characterisation of the foam includes shear testing, and an assessment of the air flow losses in the foam. Predictions are made of the impact of a headform on padding of a range of thicknesses. The design of such padding is related to the velocity of the rugby players, and the biomechanical criteria for concussion. In the design, allowance must be made for the variability of the foam properties.

2:30 PM
Microtextural Characterization of Golf Club Heads: *Stuart I. Wright*[1]; *Matthew M. Nowell*[1]; [1]EDAX/TSL, 392 East 12300 South, Ste. H, Draper, UT 84020 USA

The properties of polycrystalline materials used in golf club head forming are known to be dependent on features of the microstructure such as grain size and/or shape that arise from the processing. Less understood is the effect of the crystallographic orientation of the constituent grains on the properties. Polycrystals exhibiting strong preferred orientation or texture tend to exhibit anisotropic behavior. In order to gain some understanding in this arena, the distribution of crystallographic orientation within the polycrystalline microstructure has been characterized using automated electron backscatter diffraction in the scanning electron microscope. Data obtained from samples of cast and forged titanium and steel heads will be presented. Orientation maps constructed from the acquired data showing the spatial distribution of orientation within the samples will be presented and the texture and anisotropy discussed.

3:00 PM
A Comparison of Cricket Ball Cores: *Timothy Ashley William Jarratt*[1]; Alison Julie Cooke[1]; [1]Cambridge University, Eng. Dept., Eng. Design Ctr., Trumpington St., Cambridge, Cambridgeshire CB2 1PZ UK

Unlike many sports, cricket balls for use in 1st class matches in the UK must pass a testing regime described in a British Standard. Various work has investigated the aerodynamic ('swing') properties of cricket balls and some has been carried out to examine the dynamic properties of balls during impacts with the pitch and bat. However, very little research is known to have been published on the cores of cricket balls, the construction of which can vary widely from traditional wound centres to composite moulded ones. This paper describes elements of a study carried out to compare some material properties of the cores of all the balls licensed for use in UK 1st class cricket with those of traditionally manufactured centres. Results show that certain types of construction can lead to 17% variation in hardness along the principal axes. These hardness variations were also apparent when complete balls were tested.

3:30 PM Break

Materials in Sport III

Tuesday PM Room: St. Tropez Ballroom Salon C
April 24, 2001 Location: Coronado Island Marriott Resort

Session Chair: V. S. Moxson

4:00 PM
Sensors in Fabrics: A New Dimension in Sport: *Gordon Wallace*[1]; Kelly-Anne Bowles[2]; Peter Innis[1]; Julie Steele[2]; Geoff Spinks[1]; Jian Wu[1]; Dezhi Zhou[1]; [1]University of Wollongong, Intelligent Polymer Rsch. Inst., Northfields Ave., Wollongong, NSW 2522 Australia; [2]University of Wollongong, Biomech. Rsch. Lab., Northfields Ave., Wollongong, NSW 2522 Australia

Development of inherently conducting polymers (ICP) as both sensors and actuators has been the focus of intense investigation for two decades. Recent integration of ICP into fabrics, either by coating fabric or weaving preformed ICP fibres throughout the structure, has created wearable sensors and actuators. With an appropriate host fabric, wearable sensors form a composite material with strain gauge-like properties with a wide dynamic range while the actuators can respond to these changes within the fabric. This paper describes our recent development of ICP as fabric sensors and actuators in two sports applications: (i) quantifying dynamic loading within sports brassieres and (ii) providing real-time technique feedback via fabric joint sleeves as sports injury prevention initiatives. Fabric sensors are ideal for such applications as they can be integrated directly into existing sports clothing and equipment without changing the material properties or functions of these items. We also demonstrate polymer fibre and fabric actuators that reversibly expand/contract in response to small electrical stimuli.

4:30 PM
Perception of Performance and Blade Contouring in Female Varsity Ice Hockey Players: *Kelly L. Lockwood*[1]; Brent Dalrymple[1]; Sean Reader[1]; [1]University of Regina, Fac. of Kinesiology & Health Studies, 3737 Wascana Pkwy., Regina, Saskatchewan S4S 0A2 Canada

A pilot study was undertaken to determine if female, varsity hockey players (n=13) could perceive a difference between three selected blade contours of radii (7', 9', 11') and whether perceptions of their skating performances varied as a function of the three respective contours. The radius of hollow and the apex of the contour were held constant across all cases. Questionnaire data were collected addressing (i) perception of performance and (ii) perception of blade contour. Performance variables included speed, control, and agility. Perceived differences in contour were measured via the player's ability to distinguish between the three contours. Questionnaire items were treated as dependent variables and the blade contours as the independent variable. A repeated measures ANOVA revealed that only the questions related to performance perceptions generated significant results ($p<0.05$). These findings indicated that players distinguished a difference in their performance, however, did not discriminate between selected blade contours.

5:00 PM
New Beta Titanium Alloy for Golf Club Heads: *Akihiro Suzuki*[1]; Toshiharu Noda[1]; Michio Okabe[1]; Naoyuki Masuda[2]; Mototaka

Iwata[2]; [1]Daido Steel Co., Ltd., R & D Lab. Special Steel Rsch. Dept., Corrosion/Heat-Resistant Alloys Rsch. Team, 2-30 Daido-cho, Minami-ku, Nagoya-shi, Aichi-ken 457-8545 Japan; [2]Mizuno Company, Ltd., 1-12-35 Nankou-kita, Suminoe-ku, Osaka-shi, Osaka-fu 55-8510 Japan

Titanium alloys, high strength and low density materials as compared with steels, have been popularly used for golf club heads of drivers and fairway woods. The advantage of using titanium alloys for the golf club heads is because it allows to create an oversized club head that has a large sweet spot without adding overall weight to the golf club. So far great effort has been made to produce the oversized golf club head. However, the larger the club head become, the thinner is required the wall of the club head. In order to make the wall thin further, the development of a new titanium alloy that has higher strength and toughness than conventional alloys is necessary. In this study, a new beta-titanium alloy of Ti-V-Cr-Al system with high strength and high toughness was developed based on a conventional beta-titanium alloy DAT51(Ti-22V-4Al). Chromium, one of the solid solution strengthening elements of the beta phase, was employed to enhance the strength of alloys. Vanadium content was optimized to obtain good elongation and to control the precipitation of the alpha phase. Aluminum content was kept for solid solution strengthening of the alpha phase. As a result of tensile tests and charpy impact tests, one of the designed alloys showed excellent combination of strength and toughness as compared with conventional beta alloys (Ti-22V-4Al, Ti-15V-3Al-3Sn-3Zr). Golf clubs were fabricated by using this forged alloy. The performance test of the golf club revealed its excellent performance.

Materials in Sport IV

Wednesday AM Room: St. Tropez Ballroom Salon C
April 25, 2001 Location: Coronado Island Marriott Resort

Session Chair: Hugh Casey

9:00 AM
Production of Sports Equipment Components via Powder Metallurgy: *V. Moxson*[1]; J. Qazi[2]; S. Patankar[2]; F. H. Froes[2]; [1]ADMA Products, Inc., 8180 Boyle Pky., Twinsburg, OH 44087 USA; [2]University of Idaho, Inst. for Mats. & Adv. Proc., Mines Bldg., Rm. 321, Moscow, ID 83844-3026 USA

The powder metallurgy (P/M) approach is a cost-effective technique for production of components for sports equipment. In this paper, parts produced from metals as diverse as tungsten and titanium will be discussed and their use in sporting equipment demonstrated.

9:30 AM
Advanced Materials in Golf Clubs: *C. Shira*[1]; F. H. Froes[2]; [1]Carbite Golf, Nancy Ridge Dr., Ste. 107, San Diego, CA 92121 USA; [2]University of Idaho, Inst. for Matls. and Adv. Proc., Mines Bldg., Rm. 321, Moscow, ID 83844-3026 USA

The use of advanced materials such as titanium has led to golf clubs that are friendlier to the user. However, the high cost of such materials is forcing golf club designers to turn to creative designs using combinations of lower cost materials, with the lessons learned from titanium being carefully applied. These advanced materials and designs do help the golfing public. However tougher courses, and the criticality of practicing the short game, have resulted in little change in the average golf handicap.

10:00 AM
Optimized Welding and Treatment of Lightweight AL–Li Alloys for High-Performance Bikes and Hang Gliders: *I. G. Solórzano*[1]; A. C. Vidal[1]; S. Oliveira[1]; F. Darwish[1]; [1]PUC-Rio, Dept. of Mats. Sci. & Metall., Rio de Janeiro, Brazil

The influence of the fusion weld process (TIG manual) on the microstructure and mechanical behavior of 2091 and 8090 alloys (Al-Ci-Cu-Mg-Zr) has been studied. In order to evaluate the effect of heat treatment on the welded joints, some samples were subjected to solubilization and T6 artificial aging, followed by microstructural characterization, by means of light optical and electron microscopy, and mechanical testing, namely uniaxial tension, quasi-static bending, impact and fatigue. The results showed that the welding has a deleterious effect on the mechanical behavior of both alloys. The T6 treatment, however, promotes a considerable recovery effect on the mechanical performance of the welded joints. In agreement with the recovery of the mechanical performance, SEM fractographic analysis have shown that the fracture mechanism changes from essentially intergranular to dominant transgranular fashion. Searching for a criteria to unify the different results of the mechanical tests, the levels of fracture toughness has been estimated, yielding a good correlation among most microstructural conditions of both alloy described in the paper. Based upon the experimental research performed here, it is concluded that these alloys can be advantageously used in lightweight high-performance bikes or hang gliders.

10:30 AM Break

Modelling in Sport

Wednesday AM Room: St. Tropez Ballroom Salon C
April 25, 2001 Location: Coronado Island Marriott Resort

Session Chair: Jani Pallis

11:00 AM
Deformation Mode Characterisation and the Effects of Materials and Design in Oversized Golf Drivers: *M. Strangwood*[1]; E. Faulkner[1]; E. Bird[1]; H. M. Hussien[1]; S. R. Otto[2]; [1]The University of Birmingham, Sch. of Metall. & Mats., Edgbaston, Birmingham B15 2TT UK; [2]The University of Birmingham, Sch. of Math. & Stat., Edgbaston, Birmingham B15 2TT UK

A wide range of materials are used in golf driver heads with varying claims as to their performance. The use of different materials, such as steels, Ti-based alloys and amorphous zirconium (liquid metal), and processes, e.g. casting, forging and inserts, results in different head dimensions and these may relate to performance when driving. In this study, a large number (~500) of heads constructed in aluminium-based, steels, titanium-based (mostly) and zirconium-based alloys have been characterised in terms of the areas and thicknesses of their component parts (face, crown and sole) using ultrasonic measurements, image analysis and physical measurements on sectioned heads. The sectioned heads have also been characterised in terms of microstructure and hardness for all components and any joints/welds between them. In addition, the vibrational frequencies of these components have been measured, using Fast Fourier Transforms on accelerometer data for simulated face sweet spot impacts, for a selected number of heads. The frequency spectra have been compared with predicted deformation mode frequencies and coefficient of restitution measurements determined using the USGA test. The results obtained tests have confirmed that the face is not solely responsible for any enhanced ball velocity, but that deformation of the head on impact is affected strongly by modes in the, generally, thinner crown. A broad correlation between reduced dominant head vibration frequency, achieved through the use of thinner components with larger areas and COR has been established. This indicates performance benefits for heads constructed of materials with higher strength but lower modulus, but the fit is only

about 80 % because of the role of welds/joints between face and crown to distribute deformation over the head and hence increase ball velocity through reduced ball deformation and energy losses. Characterisation and modelling of these deformation modes and the role of welds/joints is currently ongoing.

11:30 AM

Modelling Impacts on Sports Surfaces: *Matthew Jon Carre*[1]; Stephen John Haake[1]; [1]University of Sheffield, Dept. of Mech. Eng., Mappin St., Sheffield S1 3JD UK

A model was developed to describe the dynamic behaviour of a sports surface during impact. It was designed empirically to satisfy a set of five conditions, known to occur during a typical impact of a rigid mass on a sports surface. Using four pre-determined coefficients, the model is capable of predicting the change in acceleration, velocity and displacement of a rigid mass during impact with a sports surface. The model was evaluated using acceleration data from impact hammer tests on a number of artificial cricket pitches as well as displacement data taken from high speed video footage of cricket balls impacting on a natural turf pitch. The results from the model were found to be in good agreement with the experimental data. A method of sports surface classification was suggested, using the empirical coefficients of the model to describe the expected surface performance under normal conditions.

12:00 PM

Comparison of Flexible and Rigid Body Modelling of a Tennis Racket: *Simon Richard Goodwill*[1]; [1]University of Sheffield, Mech. Eng. Dept., Mappin St., Sheffield S1 3JD UK

In this paper two different techniques are compared for modelling a tennis racket during an impact with a tennis ball. Experimental data was obtained for an impact between a ball and a stationary, freely suspended racket. The balls were projected at the longitudinal axis of the racket, perpendicular to the stringbed, at three discrete impact points and the ball and racket velocities determined using a high speed video system. The racket was modelled as either a rigid body or a one-dimensional, uniform segmented flexible beam. The ball was modelled as simple spring and damper in parallel while the stringbed was modelled as a spring in series with the ball. The results showed that, for impacts at the geometric string centre of the racket, the rigid and flexible beam models yield very similar results and, more importantly, both models correlate well with the experimental data. For impacts away from the geometric centre, the flexible beam model matches the experimental results better than the rigid beam model.

12:30 PM

Finite Element Analysis of Soccer Ball Impact: *Ron Thomson*[1]; Tim Lucas[2]; [1]University of Glasgow, Dept. of Mech. Eng., Glasgow G12 8QQ Scotland; [2]Adidas, Germany

Soccer is one of the world's most popular sports but, while the value of equipment sales is high, little work has been done on the mechanics of the game. The player can control launch angle, backspin, initial velocity and other parameters that affect the flight of the ball. Simple analyses based on rigid-body dynamics can be used to estimate these parameters but deeper study requires that account be taken of the large deformation of the ball on impact. This requires methods such as nonlinear finite element analysis. Modern soccer balls comprise an internally pressurized polymeric cover. A mesh of hyperelastic shells was built and assigned properties derived from physical tests. The ball was filled with fluid elements to give the pressure-volume response of air. High-speed video give a benchmark for the analysis, which is then extended to predict the effect of changes in the construction.

Sports Science

Wednesday PM Room: St. Tropez Ballroom Salon C
April 25, 2001 Location: Coronado Island Marriott Resort

Session Chair: Eric Wallace

2:00 PM

Development of Ti-Al-Al_2-O_3 Cermets for Sport Applications: *D. L. Zhang*[1]; D. Y. Ying[1]; Z. H. Cai[1]; G. Adam[1]; M. Newby[1]; [1]The University of Waikato, Dept. of Mats. & Proc. Eng., Private Bag 3105, Hamilton, New Zealand

For many sports applications such as biking and motorcycling, high strength, light and wear resistant materials such as titanium alloy based metal matrix composites are highly desirable. However, titanium alloys and titanium alloys metal matrix composites are still very expensive materials for general public. To improve the accessibility of the high performance sports gears by the general public, it is important to reduce the cost of high performance materials and components. Reducing the cost of producing titanium based materials is one of the aims of our research on developing Ti-Al-Al_2O_3 cermets. In this study, we react Al with TiO_2 to form in-situ titanium aluminides-Al_2O_3 intermetallic matrix composites or cermets. Depending on the ratio between Al and TiO_2, different aluminides are produced: Ti_3Al, TiAl and Al_3Ti. Since Al and TiO_2 are low cost materials, the cost of the composite materials is expected to be low. The hurdle for applying such materials in sports applications is their low fracture toughness because of the high volume fraction of the brittle Al_2O_3 phase, the brittleness of the intermetallic phases. In order to increase the fracture toughness of the composite materials, high energy mechanical milling has been utilised to prepare the Al/TiO_2 composite pre-cursor powders for producing the composite powders through heat treatment. The composite powders were then consolidated at temperatures as low as possible by using hot isostatic pressing to achieve fine microstructure in the final composite materials. In doing so, it is expected that dramatic improvement in the fracture toughness can be achieved. In this paper, the results of this study, especially in relation to the microstructural evolution during the reactions and the effect of the different microstructures of the cermets on their mechanical properties will be presented and discussed.

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Sport as a Method for Social Integration of Children with Spine Injuries: *Velika Miroslavova Kambourova*[1]; Violeta Damianova[1]; [1]Bulgarian Academy of Sciences, Inst. of Mech. & Biomech., 22 Hristo Smirnenski Str., 44 Latinka Str., Sofia, Bulgaria

Spine injuries are frequent deformations of the passive part of the motion apparatus area. The model of the spine, together with the adjoining muscles and the ligament apparatus, is constructed on the base of the three-dimensional finite-elements method. Special mathematical techniques are used to calculate the quantitative changes in the internal tension of the developed model in cases of scoliosis. The choice of the sport for rehabilitation is based on a colored visual computer representation of the changes in tension in the created spine model, its digital equivalent in Pa (Pascal) and depends on the personal characteristics of the patient. The program is used for kifosis and lordosis too. The possibility to personally choose the sport, helps decreasing the psychological stress in children. The individualization of the rehabilitation process is keeping the sport as a leading method for social integration of children with spine injuries.

3:00 PM

3D Kinematic and Kinetic Analysis of Two Methods for Track Start Technique in Swimming: *Roozbeh Naemi*[1]; Ahmad Reza

Arshi[1]; [1]Amirkabir University of Technology, Biomech. Eng., No4-13th st-Mahestan ave-Sharak Gharb, Tehran 14657 Iran

This study is aimed at the comparisoning of two methods of track start: TRCR (Track start with Right foot at the front edge of platform) and TRCL (Track start with Left foot at the front edge of platform), using 3D simultaneous and synchronized kinematic and kinetic analysis. 8 university swimmers, all expert in both two methods, performed 3 trials of each method. Over 50 variables including parameters from Forceplate and Motion analyzer in conjunction with time parameters are used to compare these two methods. ANOVA results indicates that TRCR is significantly more capable to produce higher propulsive reaction force and reaction moment about propulsive axis. TRCL is significantly higher in CM resultant velocity, force, and impact, resultant moment and moment of momentum about CM. The conclusion is that TRCL has less Block, Flight and Glide times and is faster than TRCR for the first 8m of the race.

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Plantar Pressure in Dancesport: *Wunching Lyle Chang*[1]; Hwei Hwei Yeo[1]; Chun-Hsien Chen[1]; [1]Nanyang Technological University, Sch. of Mech. & Prod. Eng., Nanyang Ave., Singapore 639798 Singapore

To investigate the effects of heel heights of dance shoes on dancers in dancesport (ballroom dancing), plantar pressure distribution of 7 female competitive dancers was measured with an insole pressure measurement system. The subjects performed basic steps of both Cha Cha Cha and Rumba in dance shoes with a heel height of 0 cm. The same procedure was repeated for a higher heel height of 6.35 cm(2.5 in). With 0-cm heel height, peak plantar pressure in Cha Cha Cha was 21% higher than in Rumba. When the heel-height was raised to 6.35 cm, peak plantar pressure in Cha Cha Cha was 90% higher than in Rumba. For Rumba, raising the heel height from 0 cm to 6.35 cm resulted in an increase of 40% in peak plantar pressure. A sharper increase, 83%, of peak plantar pressure in Cha Cha Cha was observed under the same condition.

4:00 PM

Instrumental Manipulation of Organism's Physical Abilities: *A. I. Kutmin*[1]; V. N. Ivanitskiy[1]; [1]Tomsk State University

At present within the framework of Tomsk State University of Architecture and Building, Tomsk, Russia initiative a technology of artificial manipulation of organism's reserve abilities is being developed. With the help of this technology the functional indices of man's abilities may rise by more than 10 times. This technology is built on well-known possibilities of regulative genes antisense inhibition with the help of synthetic oligonucleatids. Such treatment of the previously found coping regulative gene suppressors of organism's quantitative indications [Kutmin A.I., co-authors, 1998, 2000; Kutmin A.I. at al., 1999] may cause a release of the genes that are involved in the indications forming and, as a result, it may cause a dramatic increase of indications values. Practical implementation of this idea may result in losing common sense in physical qualities competition between athletes. Thus, sports will have only educational, sanitary and esthetic functions (but not competitive). Once artificial manipulation will mean tenfold increase of organism's reserve abilities, which are practically equal, there will be a competition of manipulation technologies. Thus, development of such technologies is potentially dangerous, because it is directed at getting to the organism's reserve abilities limits, which are not endless. That is why one should be very cautions and thoughtful in their implementation. At the same time a similar goal looks promising for the whole mankind, so, no doubt, it is both scientifically and practically important.

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