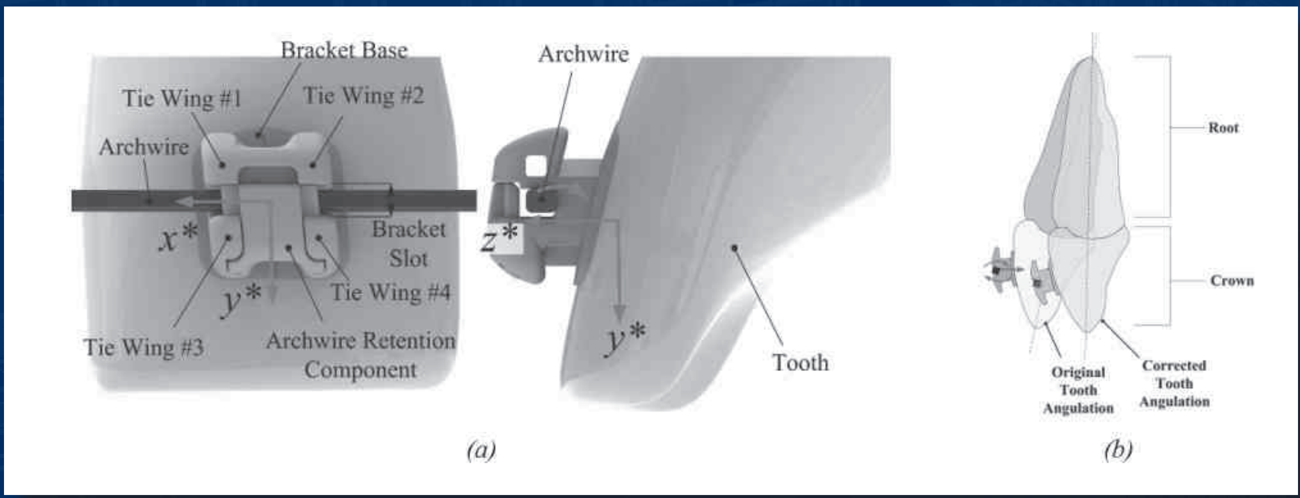
CSME BULLETIN SCGM

THE CANADIAN SOCIETY FOR MECHANICAL ENGINEERING
LA SOCIÉTÉ CANADIENNE DE GÉNIE MÉCANIQUE

Three Dimensional Deformation of Orthodontic Brackets

Story Page 10



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President's Message/Message de la Présidente

Christine Wu, Ph.D., P.Eng., FCSME

President's Message

Although I have only been CSME President for five months, I have been deeply inspired by the commitment and dedication of our members who put their collaborative efforts in various areas to better serve our members and community. It is this dedication and commitment that makes CSME a remarkable organization.

I am delighted to inform you that CSME has signed the agreement to work with the NRC to organize the 24th International Congress of Theoretical and Applied Mechanics (ICTAM) to be held in Montreal, QC, during the period of August 21-26, 2016. ICTAM is a worldwide organization that holds a major conference on Theoretical and Applied Mechanics in different countries. Canada hosted ICTAM 32 years ago and, under the leadership of Professor Floryan (Chair of MME Department, UWO), Canada has competed successfully on behalf of the NRC and CSME to have the ICTAM(2016) in Montreal. I would like to encourage you all to actively participate in this conference. This is a great opportunity to showcase the Canadian mechanical engineering community to the world. I am also glad to inform you that CSME will sponsor the 3rd EIC Climate Change Technology Conference (CCTC 2013), which will take place at Concordia University in Montreal, May 27-29, 2013. World-class guest and planetary speakers from industries, academia and government will give talks on a wide range of topics related to climate change technologies.

On the membership front, it has always been the highest priority for CSME to expand our membership base and to bring members from industries and academic institutions together on a common platform. We have developed a plan to improve our service and visibility, to include Technology Member as a grade and to implement on-line dues payment.

Student chapters are an integral part of CSME, and we have developed an action plan that CSME will support student chapter activities with funding based on their request. The instructions for funding applications and reporting have been proposed. A webmaster for the newly developed CSME homepage has been appointed, and in consultation with the Chair of Student Affairs, the webmaster will publicize all relevant activities for Student Chapters.

CSME Bulletin is the main communication vehicle for CSME with our members. Together with the newly developed CSME homepage, we plan to publish more activities from technical committees, student chapters, success stories of our members, profiles of successful Canadian mechanical engineering companies, and other CSME initiatives. I strongly encourage our members to share your stories and ideas to make CSME Bulletin and homepage a truly attractive vehicle to connect our members and to attract new members.

I would like to take this opportunity to thank Dr. David Naylor (Chair of Membership committee), Dr. Sushanta Mitra (Chair of Student Affair Committee), Dr. Xiaodong Wang and Dr. Kamran Siddiqui (Editors of CSME Bulletin) for making the action plans possible. I would also like to thank Dr. Amor Jnifene, Royal Military College of Canada, for his outstanding service to CSME. Dr. Jnifene has led the Student Design Competition committee and organized its annual design competitions at CANCAM 2011 and CSME International Congress 2012.

As we look forward to 2013, achieving our goals, whether helping formulating education, research and government policies in keeping with the real needs of Canada or better serving our members and community, will take more than CSME. We must reach out to collaborate and to establish partnerships with other professional societies. We must put our efforts collaboratively to stay relevant and to extend our functionality and effectiveness.

I wish everybody a wonderful holiday season.

Christine Wu, Ph.D., P.Eng., FCSME
Professor and NSERC Industrial Research Chair Department of Mechanical and Manufacturing Engineering, University of Manitoba

Je suis président du CSME que pour cinq mois, mais déjà j'ai été profondément inspirée par l'engagement et le dévouement de nos membres qui ont mis leurs efforts de collaboration dans divers domaines afin de mieux servir nos membres et la communauté. C'est ce dévouement et l'engagement qui fait CSME une organisation remarquable.

Je suis heureux de vous informer que CSME a signé l'accord pour travailler avec le CNRC pour organiser le 24e Congrès International de Mécanique Théorique et Appliquée (ICTAM) qui se tiendra à Montréal, QC, durant la période de 21-26 Août 2016. ICTAM est une organisation mondiale qui organise d'importante conférence sur la mécanique théorique et appliquée dans différents pays. Le Canada a accueilli ICTAM il ya déjà 32 ans et, sous la direction du professeur Floryan (président du département MME, UWO), le Canada a réussi a avoir le ICTAM à Montréal en 2016. Je voudrais vous encourager à participer activement à cette conférence. Il s'agit d'une excellente occasion de mettre en valeur la communauté du génie mécanique aux Canada. Je suis également heureux de vous informer que CSME parrainera la 3e Conférence CPN technologies du changement climatique (CTCC 2013), qui aura lieu à l'Université Concordia à Montréal, le 27 au 29 Mai, 2013. Des experts très renommé de l'industrie, des universités et des gouvernements adresserons un large éventail de sujets liés aux technologies du changement climatique.

Sur le front de l'adhésion de nouveau membre, il a toujours été une priorité pour le CSME d'élargir notre base pour amener l'industrie et les institutions académiques sur une plate-forme commune. Nous avons élaboré un plan pour améliorer notre service et notre visibilité, afin d'inclure des Membre de Technologie et à mettre en œuvre paiement des cotisations en ligne.

Le chapitres étudiants fait partie intégrante du CSME, et nous avons élaboré un plan d'action. Le CSME appuiera les activités de chapitre d'étudiants avec un financement basé sur la demande. Les instructions pour les demandes de financement et des rapports ont été proposées. Un webmaster pour le site CSME nouvellement développé a été nommé, et en consultation avec le président des affaires étudiantes, le webmaster fera connaître toutes les activités pertinentes relie aux chapitres étudiants.

Bulletin CSME est le véhicule principal de communication pour CSME avec nos membres. En collaboration avec la page d'accueil nouvellement développé, nous avons l'intention de publier d'autres activités des comités techniques : chapitres étudiant, les réussites de nos membres, les profils de la réussite des entreprises canadiennes du secteur du génie mécanique et des initiatives du CSME en autres. J'encourage vivement nos membres à partager vos histoires et vos idées pour rendre le Bulletin CSME et la page d'accueil un véhicule pour relier nos membres et à attirer de nouveaux membres.

Je voudrais profiter de cette occasion pour remercier le Dr. David Naylor (président du comité d'adhésion), le Dr. Sushanta Mitra (Président du Comité affaire étudiant), le Dr. Wang Xiaodong et le Dr. Kamran Siddiqui (éditeurs de Bulletin CSME) pour leur plans d'action. Je tiens également à remercier le Dr. Amor Jnifene, Collège militaire royal du Canada, pour sa contribution exceptionnelle au CSME. Dr. Jnifene a conduit le comité Concours étudiant de conception et d'organisation de ses compétitions de design au CANCAM annuels 2011 et CSME Congrès international 2012.

Pour atteindre nos objectifs, que ce soit pour aider la formulation de l'éducation, ou de la recherche et des politiques gouvernementales en accord avec les besoins réels du Canada, ou pour mieux servir nos membres et la communauté, cella prend plus que le CSME. Nous devons tendre la main à collaborer et à établir des partenariats avec d'autres associations professionnelles. Nous devons mettre nos efforts en collaboration pour rester pertinent et d'étendre notre fonctionnalité et l'efficacité.

Je souhaite à tous un joyeux temps des Fêtes.

Christine Q. Wu, CSME Président

CSME Advertising

Contributing to the CSME Bulletin

We welcome submissions of events, announcements, job postings, and feature articles relevant to mechanical engineering from researchers and engineers in Canada. Feature articles in forms of both review and research papers are welcome. The articles should be technical, general, and no more than 6000 words. If you are interested in submitting an article to the Bulletin, please contact the Editor at xiaodong.wang@ualberta.ca.

Contributing to the CSME Bulletin

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Happy 300th Anniversary to the Steam Engine

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Having worked my entire career in energy and applied thermodynamics, I would be remiss if I did not take this opportunity to celebrate the 300th anniversary of one of the most important inventions in the history of mechanical engineering and, arguably, all humanity. For it was in 1712 that Thomas Newcomen introduced the atmospheric steam engine, which turned out to be a forerunner of all reciprocating engines and, according to some [1], a predecessor of many transportation devices, including the automobile.

Thomas Newcomen (1663-1729) was born in Dartmouth, England, near a part of the country noted for mining. Flooding was a significant challenge, limiting the depth at which mining could be carried out. Newcomen's engine was intended for pumping water, as a means of overcoming the flooding problem.

Engines of that era had worked by using condensed steam to make a vacuum, and earlier pumps had used the vacuum to pull water up. Newcomen created a vacuum inside a cylinder, which pulled down a piston. A rocking beam, a type of lever, was used to transfer the force to the pump shaft that descended into the mine. The invention constituted first practical engine to use of a piston in a cylinder [1].

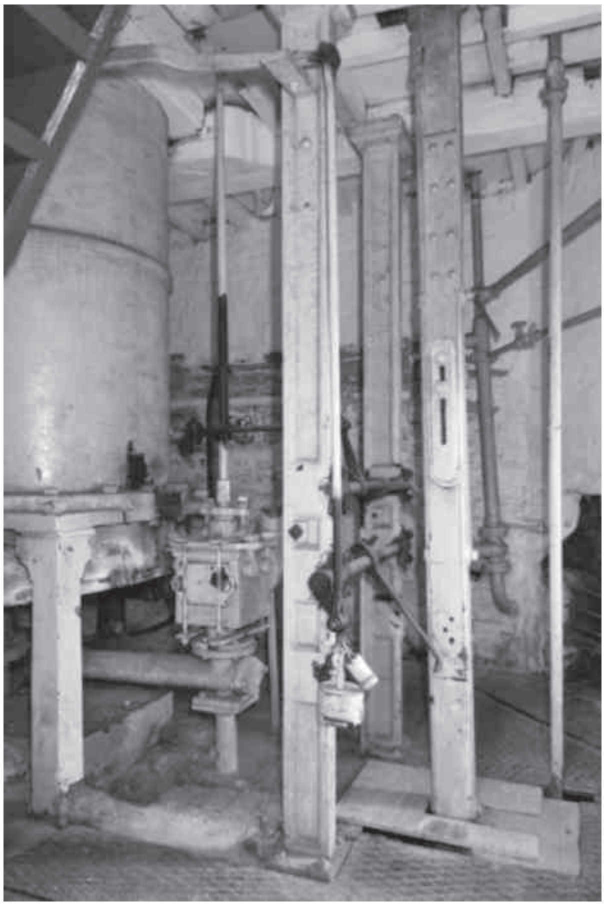
Although a complicated engineering achievement for the early eighteenth century, the Newcomen Engine was not terribly efficient. It has been noted [2] that, "Much heat was lost when condensing the steam, as this cooled the cylinder. This did not matter unduly at a colliery, where unsaleable small coal (slack) was available, but significantly increased the mining costs where coal was not readily available, as in Cornwall. Therefore, Newcomen's engine was gradually replaced after 1775 in areas where coal was expensive (especially in Cornwall) by an improved design, invented by James Watt, in which the steam was condensed in a separate condenser."

Newcomen engines remained in use for a considerable time and thousands were built, the last in 1906. A recent letter to ASME Magazine [3] notes, "… his design was in production, unchanged, for more than 50 years. Hundreds of his original engines ran non-stop for years and lasted for generations."

Upon viewing one of the surviving Newcomen engines during a recent visit to the Science Museum, London, England, I found it difficult not to be awed by both the impressiveness of the device and its importance to the Industrial Revolution and so many subsequent inventions. Many claim that Newcomen's invention heralded the beginning of the development of practical thermal prime movers [4].

The significance of Newcomen's invention has been recognized broadly. For instance, the ASME's History and Heritage Committee declared the Newcomen Engine (1712) as its 70th landmark [4]. Also, Britain's Royal Mail released a stamp featuring Newcomen's atmospheric steam engine on 23 February 2012, as part its Britons of Distinction series [5].

As someone who tries to help students learn about engines, both modern and old, I am grateful to – and inspired by – Thomas Newcomen for what he gave to the world 300 years ago.



Newcomen Beam Engine at Elsecar in South Yorkshire, United Kingdom (internal view at left, and external view at right). This Newcomen Engine is the last Newcomen Atmospheric Engine to remain on its original foundations [6]. Photographs copyright Chris Allen and licensed for reuse under the Creative Commons Licence.

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A Breath of Fresh Air

The story of Gerry Price

When you think of glamorous industries, chances are that the ventilation equipment business isn't one of them. Gerry Price knows that.

But as the chairman and CEO of the Price Group of companies, the Winnipeg-based manufacturer of heating, ventilation and air conditioning products, he also knows that something as simple as the air quality of a building is vital for the people who live or work there.

And as much as something so important can be easily overlooked, so too can Price. A successful business leader, Price nevertheless prizes modesty. When asked why he's been awarded the 2012 University of Manitoba Distinguished Alumni Award, his answer is simple.

"I think it's why they chose to nominate me that's relevant, not why I think I was nominated," says Price.

A quick consultation with award nominator and Faculty of Engineering Dean Emeritus Doug Ruth sheds some light on this. Ruth first met Price in 1967, when they were both studying mechanical engineering at the university.

"He is the role model, as far as I'm concerned," says Ruth. "He's academically smart, but he's also street smart. He's open, warm and true to his friends. It's rare that you get that combination of a person who's driven and who's nice."

That drive is clear. After obtaining his PhD in mechanical engineering and applied mechanics in the United States, Price worked as a scientist for the Defense Research Board in Alberta. In 1977, he joined the family ventilation equipment business founded by his father. Within a decade, Price was running the company. By the mid-1990s, he had bought out the company's remaining shareholders in order to take full control of the firm.

"I kinda like being in charge of my own ship, if you like," says Price. "I had ideas of what I wanted to do in the business, and I wasn't sure others would be interested in taking the risk with me."

One of those risks: expanding the business south of the border. It was a bold move; Price says the company lost a 'ton of money' for seven years.

"At the same time, our Canadian business entered into a deep recession," says Price. "Because between 1987 and 1993, we lost two-thirds of our Canadian non-residential construction market. For a number of years, we had to find every considerable way to save money, keep the doors open, meet payroll and keep the business viable in Canada."

Price attributes his company's turnaround to many factors, including its strong research and development and rolling out new products with short lead times. He also says the company's commitment to customer service and principle-based values helped it eventually break even.

"It's a business model not practiced by very many companies," says Price. "People give lip service to it, but very few actually execute on it."

Ruth says Price's dedication to keeping 800 employees as well as company headquarters in Winnipeg is nothing less than outstanding.

"What he's done is move the manufacturing facilities to other places in the world, because that's what you've got to do," says Ruth. "But what he has [also] done, is he's kept all the high-end—all the engineering, design, management— in Winnipeg."

Today, Price owns or controls eight companies operating under the Price Group. Last year, those companies had sales of $331 million, 12 manufacturing sites and more than 2,200 employees.

Nevertheless, the 63-year-old continually evaluates his business, and himself, against other leaders in the market, always looking for an opportunity to learn.

"When you hear the great story of somebody with a new approach or some insight on leadership, or this-or-that, I capture it," says Price. "I write notes, I clip articles. I've got files on leadership and things like this."

Price is a driven, committed, individual, says Ruth—and that energy goes far beyond the office swivel chair. He volunteers for numerous non-profits, and has long been involved in helping U of M students better prepare for life in the work world through his involvement with the Faculty of Architecture Partners Program, the Asper School of Business Associates Program, the Faculty of Engineering Friends program and raising funds to build the university's Engineering and Information Technology Complex.

Many of Price's donations are given quietly, below the radar. Money, he says, has never been an objective in his life, but rather a byproduct of a successful business.

"You know, you're not judged in life by what you have on your death bed," says Price. "The legacy that counts is the people who have benefitted, loved and appreciated your being part of their life. That's the only legacy that counts. Nothing else counts. Period."

Of all his charitable endeavours, one remains most personal.

The Travis Price Classic is an annual charity golf tournament held in memory of Price's son, who died suddenly while playing hockey for St. Johns- Ravenscourt in 2004. Travis's childhood friends conceived the event and Gerry is a member of the committee. In its first two years, the tournament raised $350,000 for Camp Brereton, an outdoor getaway for kids of all abilities in the Whiteshell Park region that's run by Variety, the Children's Charity of Manitoba.

The money helped build a new sports court at the camp, and a new camp lodge is scheduled for completion this fall.

"Gerry is truly a leader in the community," says Variety executive director Wayne Rogers. "He's just a stellar human being."

"You know, you're not judged in life by what you have on your death bed," says Price. "The legacy that counts is the people who have benefitted, loved and appreciated your being part of their life. That's the only legacy that counts. Nothing else counts. Period."

(Stories by Sarah Richards, copy and images reprinted with permission of On Manitoba magazine)

Article recommended by Dr. Christine Wu

Women in Engineering: Moving Manitoba into the Future

by Christine Wu

"Women in ME" is a group of woman undergraduate and graduate student from the Department of Mechanical Engineering, University of Manitoba. The group was co-founded by Dr. Christine Wu, P. Eng., a professor from Mechanical Engineering and Ms. Heather Smart, P. Eng., a mechanical engineer, who has worked at StandardAero for 12 years and is currently pursuing her M.Sc. degree at the Department of Mechanical Engineering, University of Manitoba. The goal of "Women in ME" is to network, share experience and facilitate mentorships with woman engineers from industry, academia and government.

Women in ME was formed in October 2012, and meets monthly. In the October gathering, Dr. Wu and Ms. Smart gave a joint talk "Women in Science and Engineering-Celebration! Leaky pipes?" Dr. Wu presented the brief history of progress of advancing women's status in academia, challenges faced from a woman's perspective and success stories. Ms. Smart presented the current status of woman engineers in Canadian and Manitoban industries, and discussed some personal insights into working in industry.

Women in ME invited a guest speaker, Ms. Lindsay Melvin to their 2nd gathering on November 14, 2012. Ms. Melvin, a double grad from Mechanical Engineering at the University of Manitoba (B.Sc.02 and M.Sc.04), made a presentation titled "Women in Engineering: Moving Manitoba into the Future". Ms. Melvin is a Professional Engineer working at Manitoba Hydro as the Senior Market and Risk Studies Engineer in the Export Power Marketing Department. Ms. Melvin chairs the Committee for Increasing the Participation of Women in Engineering, a subset of the Association of Professional Engineers and Geoscientists of Manitoba (APEGM), and also chairs the Women's Advisory Group for Engineers Canada, the national regulating body for Canadian Engineers. In her talk, Ms. Melvin provided an overview of the current and potential future of women in engineering in Manitoba. She shared with the audience her perspectives of the engineering workplace, offered her view on the link between school and the workplace, and communicated provincial and national initiatives which support women in engineering.

In the evening, the ladies from Women in ME joined 125 female alumni, students and faculty members from the Faculty of Engineering and participated in a special Celebration of Women in Engineering event, highlighting achievements and challenges the faculty faces with regard to attracting women to engineering. During the day, the Faculty of Engineering hosted 110 girls from high schools throughout the province of Manitoba at the outreach event Engineering IS for Girls. Dr. Wu and her female colleagues opened their research labs to the girls and showcased their research activities. The girls also had opportunities to try a hands-on activity to walk a passive dynamic walker.

"One challenge our students face is that they know little about what is after their university engineering program. Through various networking activities and professional development workshops, we hope to help bridge the gap, encourage and empower our woman students to enter the engineering work force," stated by Dr. Wu. The students have very positive response:

"I just wanted to thank you both again for your presentation and for gathering this group together. ...I left today feeling re-motivated to meet and surpass challenges and don't have the words for the appreciation I feel for having a supportive network free of judgment."

"Thanks for the great speech for today's gathering, it was interesting and inspiring. Not only to realize some facts from your speech, but also learn the attitude for our life…. And look forward for the next event! Thanks for organizing this informal group!"

"…It was very interesting for me to see how much impact we can make and opportunities we have even as women."

Students from Women in ME and female alumni from mechanical engineering attended the talk "Women in Engineering: Moving Manitoba into the Future" by Ms. Melvin.




Dr. Wu discussed her research program with the high school girls participating in "Engineering is for Girls" and some girls tried operating a passive dynamic walker.


The special event "Celebration of Women in Engineering" was organized by the Faculty of Engineering, University of Manitoba. 125 female alumni, students and faculty members from the Faculty of Engineering participated.

Three Dimensional Deformation of Orthodontic Brackets

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Abstract— Archwire rotation is used by orthodontists to correct the inclination of teeth in the mouth. Deformation of orthodontic brackets is measured using an orthodontic torque simulator that reproduces the effect of archwire rotation on orthodontic brackets. This orthodontic torque simulator will provide knowledge of the deformation of orthodontic bracket that will aide clinicians by describing the effect of archwire rotation on brackets. Deformation of the orthodontic bracket is measured using a 3D digital image correlation process to quantify elastic and plastic deformation. The method used to measure 3D bracket deformation of orthodontic brackets and the results of a sample bracket are presented.

Keywords - digital image correlation, orthodontic bracket, contact-free optical strain measurement

I. Introduction

Orthodontic braces are commonly used by orthodontists to correct malocclusions (tooth misalignment) [1,2]. Braces are typically worn for over two years and patients require regular checkups to monitor and adjust tooth realignment [3]. Braces consist of a series of brackets bonded to the crown of individual teeth and an archwire passing through each bracket. Tooth motion for re-alignment is achieved by applying forces and moments to the crown of the tooth through the interaction of the archwire with the bracket [1].

One particular orthodontic treatment utilizes archwire rotation to control the anterior inclination of a tooth [4,5] Control over the amount of tooth inclination is necessary in orthodontic treatment to maintain post treatment stability and to maintain healthy alignment of the teeth [6]. Archwire rotation can result in both elastic and plastic deformation to the orthodontic bracket through contact between the bracket slot and the archwire and this can alter how the bracket responds to subsequent archwire rotations [7,8]. The small size, complicated geometry and complex loading conditions of orthodontic brackets make most conventional measurement methods impractical. Collaboration between the departments of Mechanical Engineering and Dentistry at the University of Alberta has resulted in the development, design and construction an optical method to measure orthodontic bracket deformation. This optical based measurement system utilizes a full-field digital image correlation (DIC) technique in order to measure the deformation of orthodontic brackets.

The full field DIC measurement technique has been successfully used by [7-9] to measure the two dimensional (2D) deformation of orthodontic brackets. Since a single camera was utilized this method is limited to only measuring in plane motion. Measurement of the out of plane component of bracket deformation requires the addition of a second camera. The ability to measure 3D deformation of orthodontic bracket will enable for the archwire-bracket interaction to be fully described. Understanding the three dimensional (3D) deformation of orthodontic brackets will also allow for the eventual validation of a finite element model for the archwire and bracket interaction. The objectives of this paper are to detail the method used to measure 3D deformation of orthodontic brackets and to present the results of a sample bracket using this method.

A. Mechanics of Orthodontic Brackets

Illustrated schematics of orthodontic brackets are shown in Fig.1 which shows the bracket base, tie-wings and an archwire in reference to a central incisor tooth. The bracket base is bonded to the tooth using a dental adhesive. The tie-wings provide a retentive means to maintain the archwire in the bracket slot. Fig.1 (a) shows the coordinate system that has been assigned to the center of the bracket base (x^*,y^*,z^*), where the x^* axis is parallel to the archwire and the y^* axis is defined as the direction of lateral motion of the bracket tie-wings due to archwire rotation. The z^* axis is defined as the direction from the bracket base to the top of the bracket tie wings. Archwire rotation occurs about the x^* axis and the angle of archwire rotation is defined as Φ. Change of anterior tooth inclination is achieved by rotating an archwire within an orthodontic bracket slot as shown in Fig.1 (b).

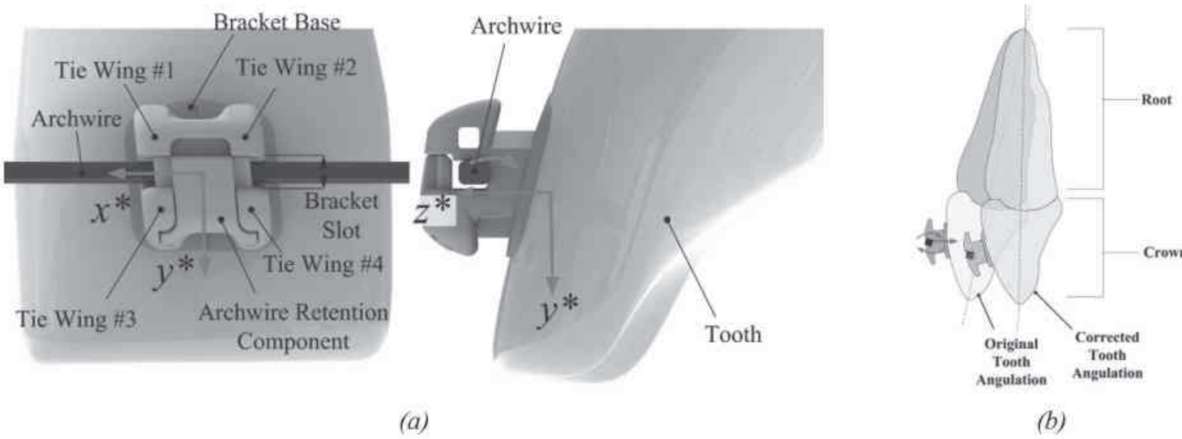


Figure 1: Schematic of an orthodontic bracket mounted on a tooth. (a) Front view and side view of the bracket showing tie wings, archwire and bracket base (b) Control of tooth angulation using archwire rotation

II. Methods

A. Description of the Orthodontic Torque Simulator

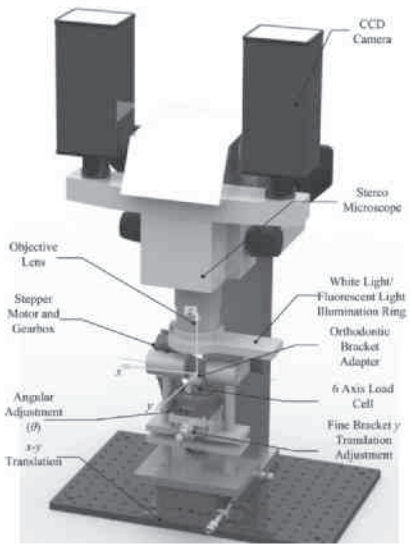
To investigate the interaction of the archwire and bracket a physical simulation of archwire rotation within a bracket slot was developed. The Orthodontic Torque Simulator (OTS) presented in Fig.2 shows a rendered image of the device. This figure also shows the coordinate system (x,y,z) used to position the OTS in the microscope field of view. The custom testing device was required to simulate the clinical situation of archwire rotation and measure the loads applied to the bracket. The overhead imaging system collects images of the brackets allowing for DIC to be performed on the brackets to identify bracket deformation. Fig.2 shows the dual camera system coupled with a stereo microscope used to collect images of the orthodontic brackets. The OTS is positioned in the microscope field of view using three translation stages (LT01 Translation Stage, Thor Labs, Newton NJ, USA). The height (z) of the microscope above the OTS is adjusted to focus the bracket image. The position (x,y) of the OTS is also adjusted using these translations stages to center the bracket in the microscope field of view.

Archwire rotation is achieved using a computer controlled stepper motor and gear box. Two dies, used to clamp the archwire, are mechanically locked together by a yoke to provide support to the archwire and even rotation from both sides. A 6-axis load cell is also used to collect force and moment data applied to an orthodontic bracket due to archwire rotation. The complete details of the OTS design have been described by [6-9].

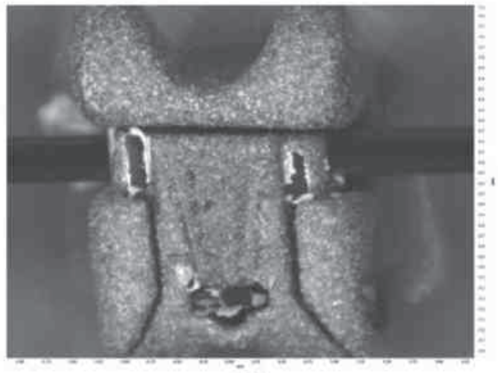
B. Stereo Microscope and CCD Cameras

2D deformations of orthodontic brackets have been performed using the OTS device [7-9]. The details of the equipment used in the OTS for in-plane deformation are detailed by [6-9]. The addition of a stereo microscope allows for the in-plane (x*,y*) motion of the orthodontic bracket to be measured as well as the out of plane motion (z*).

The stereo microscope version of the OTS is comprised of a stereo microscope (Zeiss SteREO Discovery v8 microscope Carl Zeiss Micro Imaging GmbH Göttingen, Germany) with a 60mm working distance objective lens (1.0X Zeiss V8 Plan Apo Objective Lens, Zeiss MicroImaging GmbH Göttingen, Germany). Images of the orthodontic brackets were collected using two CCD cameras (Imager Intense, LaVision GmbH, Göttingen, Germany) at 1376×1040 pixels and 12-bit resolution. The brackets were imaged at 2.0x magnification to ensure the entire bracket is in the camera field of view. Test specimens are illuminated using a ring light (2.64” Ring Light, Variable Frequency, Edmund Optics, Barrington, NJ, USA) to provide even illumination across the field of view. The brackets were illuminated using a 365nm black-light (Black (365nm Peak) Replacement Bulb, Edmund Optics, Barrington, NJ, USA).




(a)


(b)

C. Digital Image Correlation

Digital Image Correlation (DIC) is a full field optical measurement technique that uses a random speckle pattern on a specimen surface to measure deformations and strains [10]. This method is advantageous as it does not require contact with the specimen contrary to strain gauges for example. Deformation is measured by tracking contrast features on the specimen surface between subsequent images [11]. Each digital image is segmented into evenly spaced subsets and an image correlation algorithm is performed for each image subset. The average displacement in each subset is then determined as the displacement vector from the center of the region to the maximum of the correlation function. DIC can be used in 2D or 3D configurations. The 2D configuration (single camera) allows for in-plane motion (x*,y*) to be measured whereas the 3D configuration (2 or more cameras) allows for both in-plane and out of plane motion (x*,y*,z*) [12]. DIC displacement measurement comprises of three consecutive steps (1) specimen preparation and image calibration (2) collection of specimen deformation before and after loading (3) post processing of images to determine displacement or strain [13]. A specimen is prepared by applying a random pattern to the object surface using natural surface features or paints. Images are calibrated to convert from pixels to physical space (mm, inches) by acquiring an image of a target with a grid of known spacing (Microscope Calibration Plate 0.2 to 1mm dot spacing, LaVision GmbH, Gottingen, Germany). Images collected using the OTS were acquired and post processed using a commercial software package (LaVision GmbH DaVis 8.06. Gottingen, Germany; 2009). Image subsets used in this study were 64 x 64 pixels in order to determine the 3D displacement of the brackets. The field of view for the brackets was 1376×1040 or 4.25 x 3.3 mm.

D. Sample Preparation

Orthodontic brackets were prepared by coating the surface of the bracket with green fluorescent airbrush paint (5404 Fluorescent Green Createx Airbrush Colors, Createx Colors, East Granby CT) and the paint was reduced at a ratio of approximately 2:1 to improve the flow of the paint through an airbrush (Wicked W100 Reducer Createx Airbrush Colors, Createx Colors, East Granby CT). Fluorescent paint was chosen for the speckle pattern to reduce specular reflection from the metallic bracket surfaces. The speckle pattern was applied using a high quality airbrush (Custom Micron B, Iwata Medea Inc. Portland OR). The use of an airbrush and fluorescent particles was outlined by [14]. An example of an orthodontic bracket with and without the fluorescent speckle pattern is shown in Fig.3. The reflectivity of the bracket surface can be seen in Fig.3 (a). Since the orthodontic brackets have irregular geometry the reflection of the bracket surface will vary with bracket deformation and this will affect the accuracy of the DIC measurements. A bracket with the fluorescent speckle pattern is shown in Fig.3 (b) and this figure shows that the reflectivity of the bracket surface is greatly reduced.

E. Accuracy of 3D Deformation Measurement

The accuracy of the 3D deformation measurement system was assessed by utilizing rigid body displacement [15]. A flat test sample was physically displaced in known increments and compared with the DIC measurement. The flat test sample was cut out of clear acrylic and painted black (OPTIX acrylic sheet 2.0mm thickness Plaskolite Inc. Columbus, OH). A flat test sample was chosen to simplify the rigid body analysis by eliminating complications due to irregular geometries by using a sample with regular known shape. The test sample was then speckled using the airbrush speckling method discussed in section IID. The test sample was displaced using two micrometer driven translation stages (MT01 Translation Stage, Thor Labs, Newton NJ, USA). The translation stages have a range of 12.7mm and a minimum resolution of 0.0127mm. A test sample was moved in increments of 0.0254mm using the micrometers to a maximum distance of 0.254mm. The test sample was displaced in two directions, x* and z*. The x* and z* displacements were used to assess the accuracy of the in-plane and out of plane DIC measurements respectively. Rigid body displacements in the x* and z* directions were each performed three times to reduce the effect of human error on the movement of the micrometers.

F. Measurement of 3D Deformation of an Orthodontic Bracket

To demonstrate the 3D displacement of orthodontic brackets a Damon 3MX (Ormco Corporation, Orange, California, USA) bracket was tested using the OTS. The OTS was controlled using custom designed software (LabWindows/ CVI, National Instruments, Austin TX). This program automates the control of the stepper motor, acquisition of data from the load cell and image acquisition. Using the automated OTS software the angle of the archwire, ⦶, was rotated in 3° increments to a maximum angle of 45°. Once the maximum angle was reached the archwire was returned to the original position in 3° increments. At each increment a pair of stereo images of the orthodontic bracket was collected resulting in thirty-two (32) image pairs collected. The stereo image sequence will be used to measure the 3D deformation of the bracket due to archwire rotation by post processing the images using the method described in section IIC.

Deformation of the bracket will be assessed by determining the relative motion between the four bracket tie-wings shown in Fig.4. This figure also shows the 64x64 pixel subset which was used for the measurement of the 3D displacement of the bracket. Equation (1) details the calculation of the bracket displacement in the x*, y* and z* directions. In this equation denotes the average displacement of the defined regions for Tie-Wings 1,2,3, and 4 for the i=x*,y*,z* directions. LHSD is the displacement between tie-wings 1 and 3 while RHSD is the displacement between tie-wings 2 and 4.

$$\begin{aligned} LHS_{Di} &= \left| \overline{D_{TieWing1}} - \overline{D_{TieWing3}} \right|_i \\ RHS_{D_i} &= \left| \overline{D_{TieWing2}} - \overline{D_{TieWing4}} \right|_i \end{aligned} \quad (1)$$

G. 3D DIC Bracket Deformation

Deformation of the orthodontic bracket and the 3D displacement vectors found using the 3D DIC method were visualized using a scientific visualization software package (ParaView, Kitware, Inc. Clifton Park, New York). The visualization software package was used to view the result of the bracket-archwire interaction in three dimensions in real time.

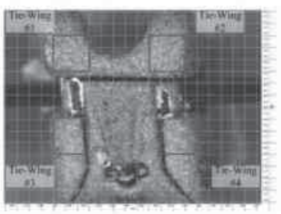


Figure 4: Orthodontic bracket box regions to track tie-wing motion.

III. Results and Discussion

Accuracy of 3D Deformation Measurement

A. The accuracy of the 3D deformation measurement system was assessed by utilizing bulk displacement. A flat test sample was moved a known distance in increments of 0.0254mm using the micrometer. It is expected that the DIC results should match the bulk displacement in the x*, and z* directions. Comparison of the correlated displacements with the actual displacement is shown in Fig.5. The in-plane bulk displacement comparison is shown in Fig.5 (a) while the out of plane displacement comparison is shown in Fig.5 (b). Both Fig.5 (a) and (b) show the results of three displacement tests as well as the actual displacement of the micrometer.

The accuracy of the 3D DIC measurement method has been assessed using a sample with a regular geometry. From Fig.5 it can be see that there is agreement between the measured 3D DIC displacement in the x* and z* directions and the physical displacements. Fig.5 shows that Test 1 for the in-plane measurement and Test 2 for the out-of-plane measurement deviated from the expected micrometer displacement. The 3D DIC measurement using a 64x64 subset size will have a resolution of 0.025 pixels [16]. Using the current camera setup the measurement resolution equates to 0.07µm. The micrometer minimum resolution is 0.0127mm therefore the deviation from the expected displacement is attributed to human error in the movement of the test sample using the micrometers. The in-plane and out of plane accuracy for 3D DIC are typically 1-2% and 3-4% respectively [17]. This indicates that the out-of-plane error should be greater than the in plane error.

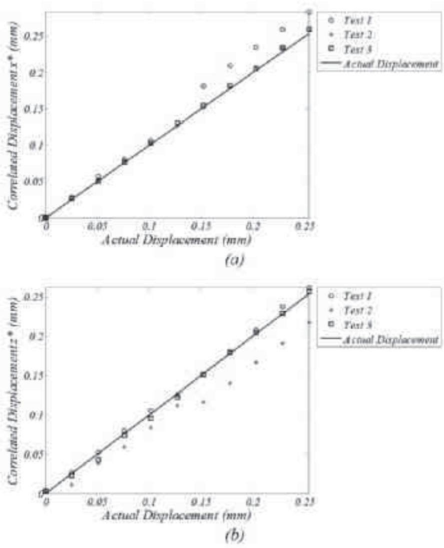


Figure 5: Digital Image Correlation Validation (a) In Plane (x) bulk translation (b) Out of plane (z*) bulk translation.*

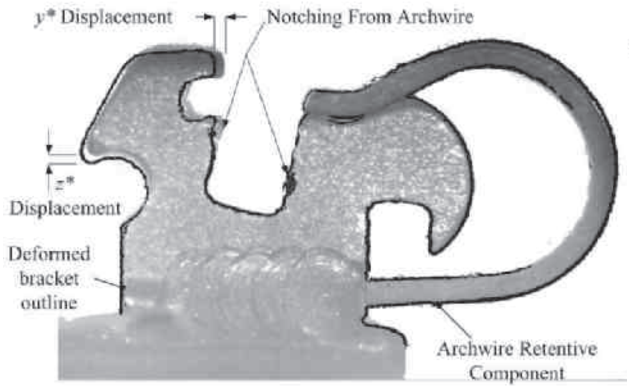


Figure 6: Profile image of an orthodontic bracket showing deformation due to archwire rotation.

B. Measurement of 3D Deformation of Orthodontic Brackets

A profile image of an orthodontic bracket is shown in Fig.6. This figure shows the bracket prior to deformation caused by archwire rotation as well as the outline of the bracket after archwire rotation. This image illustrates that the bracket tie-wings displace in both the y* and z* directions. It can also be seen that localized deformation (notching) occurs due to engagement of the archwire in the sides of the bracket slot.

Prior measurements of tie-wing displacement have been limited to measuring bracket deformation in the x* and y* directions [7-9]. The addition of a second camera to the OTS will allow for the measurement of the z* displacement.

Deformation of the orthodontic bracket was measured by post processing a sequence of stereo images collected using the OTS. Post processing of the image sequence was performed using the aforementioned 3D DIC method. An example of a pair of stereo images collected is shown in Fig.7 (a) and (b) which shows the left and right views of the bracket. This figure shows the different perspectives of the two cameras. The pairs of stereo images allows for the surface height of the bracket to be computed using the LaVision DaVis commercial software. In addition the 3D displacement of the bracket can also be calculated between sequential images.

A sequence of images collected using the OTS is shown in Fig.8 at increasing archwire rotations ( ) of 0, 21, and 45° as well as decreasing archwire rotation of 21 and 0°. This image sequence shows the archwire rotation between subsequent images. The change in light reflected by the archwire indicates archwire rotation in this image sequence. The motion of the archwire retentive component and widening of the bracket tie-wings can also be seen between Fig.8 (b) and (d). This motion is indicated by a widening in the bracket slot opening. This image sequence will be processed using the LaVision commercial software in order to quantify the motion of the orthodontic bracket tie-wings as well as the motion of the archwire retentive component.

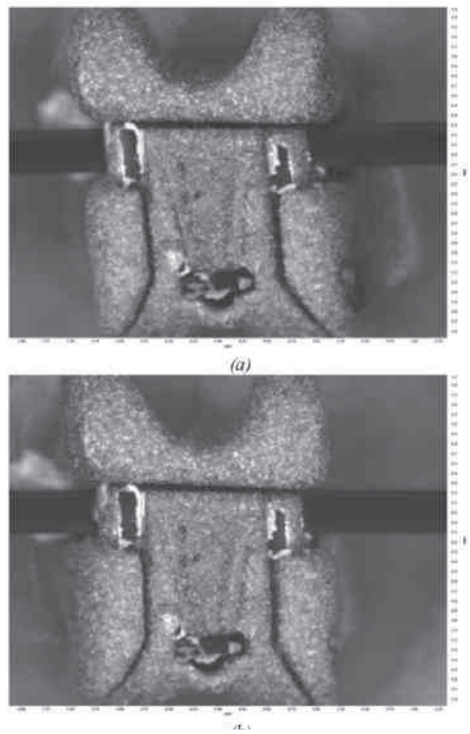


Figure 7: Stereo images of a Damon 3MX bracket showing the different camera perspectives (a) Left Camera (b) Right Camera

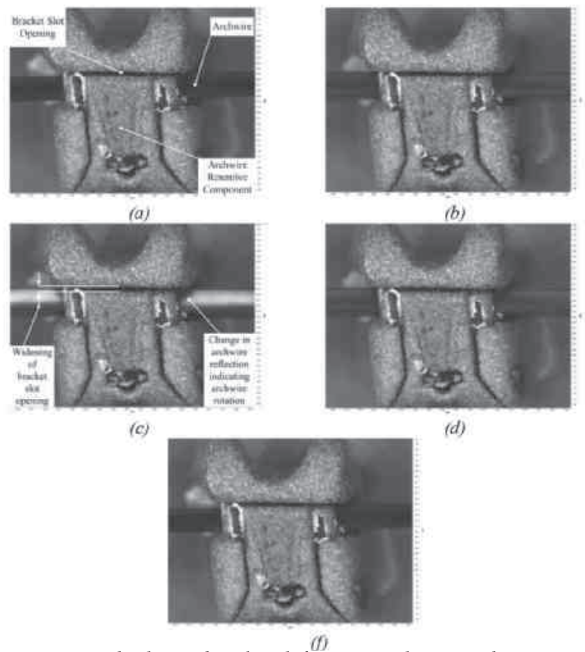


Figure 8:Orthodontic bracket deformation due to archwire rotation (⏀) (a) Increasing 0° (b) Increasing 21° (c) Increasing 45°

3D DIC Bracket Deformation

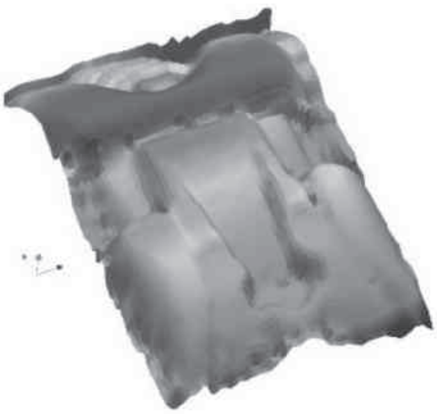


Figure 9: Three Dimensional Surface Generated using Stereo Digital Image Correlation

A 3D bracket surface created from the 3D displacement vector coordinates is shown in Fig.9. The color gradient in this image indicates the height of bracket surface. This figure shows that the stereo image pairs shown in Fig.7 can be used to generate a three dimensional surface.

A sequence of bracket surfaces and displacement vectors are shown in Fig.10. The motion of the bracket in the x*, y* and z* directions is represented by 3D displacement vectors. This figure (Fig.10 (a) to (e)) shows the displacement vectors increasing with increasing archwire rotation up to 45°. The image sequence also shows the lateral motion of the bracket tie-wings in the y* direction and motion of the archwire retentive component in the z* direction are the dominant displacement vector directions. Fig.10 (f) shows a close-up of the 3D displacement figures. This figure shows displacement vectors in the y* direction indicating the motion of tie-wings 1 and 2. Also shown are displacement vectors of the archwire retentive component. These vectors indicate that the retentive component moves in the z* direction due to archwire rotation. This image sequence demonstrates that not only does the archwire engage the bracket slot sides but also engages the archwire retentive component. The displacement vectors also indicate that greater displacement of the archwire retentive component occurs on the right hand side of the bracket than the left hand side due to possible wire misalignment or bracket manufacturing.

The results for the bracket tie wing x*, y* and z* deformation as a function of archwire rotation (Φ) are shown in Fig.11. The tie-wing deformations were determined using 1) for displacement in the x*, y* and z* directions. The maximum bracket deformations measured were -0.00292mm, 0.015468mm, and 0.011712mm for the x*, y* and z* directions, respectively. The final plastic tie wing deformations were -0.00122mm, 0.001816mm and 0.000847mm in the x*, y* and z* directions, respectively.

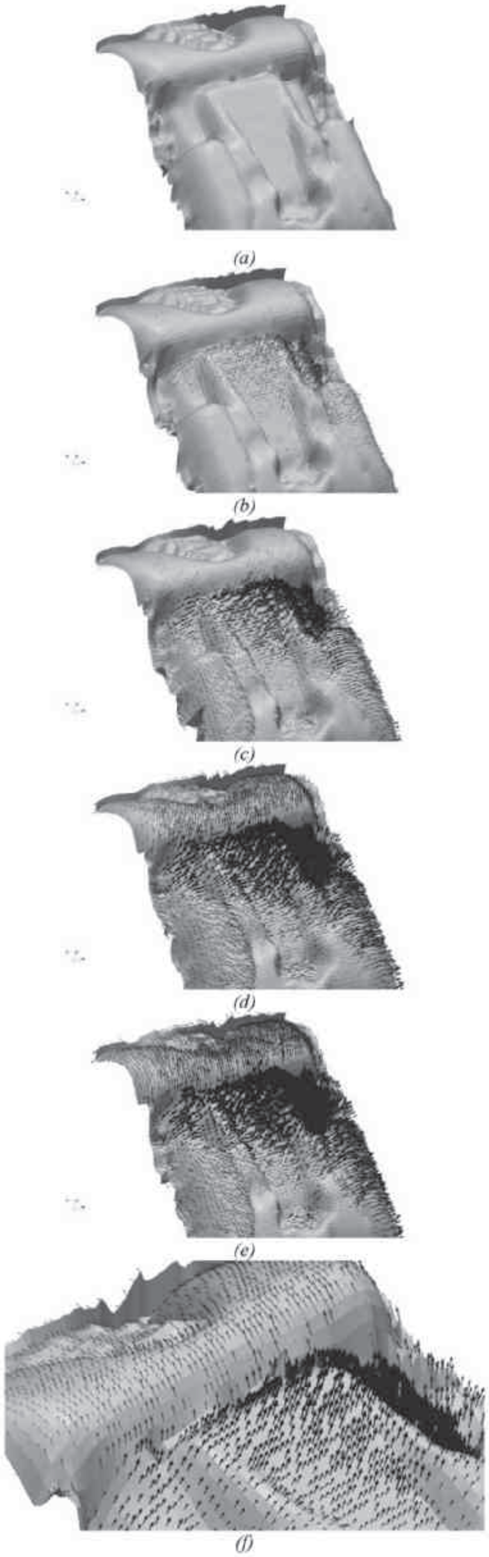


Figure 10: 3D Bracket Surface and 3D Displacement Vectors (a) 0° rotation (b) 12° rotation (c) 24° (d) 36° (e) 45° (f) Close up of displacement vectors at 45° archwire rotation

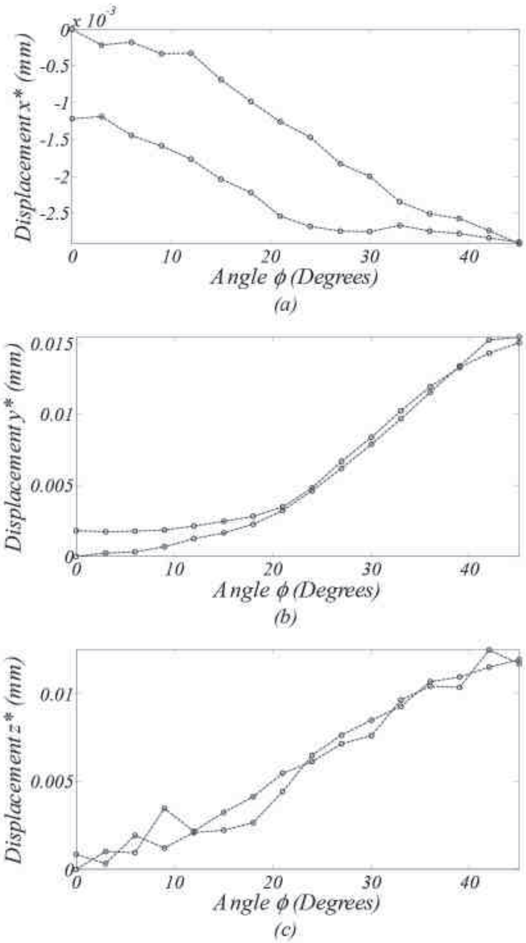


Figure 11: Orthodontic Bracket Tie-wing deformation (a) Deformation x (b) Deformation y* (c) Deformation z*.*

The image sequence (Fig.10) and deformation plots (Fig.11) show that 3D deformation can be measured and visualized using the OTS with a stereo imaging setup. These figures also show that the displacement in the x* direction is small relative to the y* and z* displacements. Fig.11 also shows that hysteresis exists between the increasing and decreasing angle (ϕ) in the x*, y* and z* directions.

The above results indicate that permanent deformation has occurred to the bracket due to archwire rotation (ϕ). Permanent deformation of the bracket in the x*, y* and z* directions will affect the behavior of the bracket for subsequent archwire rotations [18]. Knowledge of bracket deformation will aid orthodontists by describing the effect of bracket-archwire interaction and reduce the instance of prolonged treatment times due to bracket deformation.

Orthodontic brackets that have been plastically deformed can affect treatment times since brackets are used for multiple archwire rotations and a bracket with altered tie-wing geometry will not exert the anticipated force to a tooth. Understanding the 3D deformation of orthodontic brackets will help to reduce treatment times by better describing the relation between archwire deformation (x*,y*,z*) and clinically applied archwire rotation (ϕ).

The image sequence (Fig.10) also indicates that not only does the archwire engage the two sides of the bracket slot, but also engages the archwire retentive component. This is indicated by the displacement vectors acting in the z* direction. Engagement of the archwire in the bracket retentive component could affect treatment effectiveness since the archwire rotation applies a force to the retentive component instead of the expected force to the tie-wings leading to inefficient force couple transfer.

The ability to measure and visualize 3D deformation of orthodontic bracket will enable for the archwire-bracket interaction to be fully described. Understanding the 3D deformation of orthodontic brackets will also allow for the validation of a finite element model for the archwire-bracket interaction. Validation of a finite element model of the bracket-archwire interaction will lead to the investigation of loading conditions other than pure archwire rotation and other wire-bracket combinations that cannot be achieved using the OTS.

Conclusions

The small size and complex geometry of orthodontic brackets requires that a 3D DIC optical measurement technique be applied to measure the three dimensional deformation of the brackets. It has been demonstrated that it is possible to measure the bracket deformation in the x*,y* and z* directions. This technique also demonstrates the interaction between the archwire and the archwire retentive component. Accurate measurement of the deformation of orthodontic brackets may reduce patient treatment times and improve the overall success of an orthodontic operation by providing a helpful guide for orthodontists to select an appropriate amount of archwire adjustment for each treatment.

Acknowledgment

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News

The CSME International Congress (formally CSME Forum) 2012 Winnipeg, Manitoba, Canada, June 4-6, 2012

The CSME International Congress (formally CSME Forum) 2012 was held between June 4-6, 2012 in Winnipeg, Manitoba (Conference Chair: Dr. David Kuhn, Program Chair: Dr. Christine Qiong Wu). The conference attracted over 140 papers, providing valuable contributions across a wide range of mechanical engineering. 152 delegates attended with approximately 50% of these are students and 50% from academia and industry. The conference attracted strong international support from 17 countries, particularly from Australia, Canada, China, Cuba, Egypt, Germany, India, Iran, Israel, Japan, Kuwait, Malaysia, Nigeria, Norway, Saudi Arabia, United States and Venezuela. The CSME International Congress is the flagship conference of the CSME and is held biannually. The CSME International Congress 2014 will be organized by University of Toronto in June 2014.

The program for CSME International Congress was a rich mix of formats, ranging from well-known and thought provoking keynote speakers to highly interactive discussion sessions. The main conference program, included five parallel sessions with 5 symposia, 8 special sessions, 6 regular sessions and CSME Undergraduate Student Design Competition and CSME Graduate Student Best Paper Competition. In addition, three workshops and one industrial tour were organized. The conference attracted a broad range of contributions, both in the traditional areas and modern areas of mechanical engineering, from aerospace, automotive engineering, structural dynamics, robotics, manufacturing, biomechanics, material engineering to Renewable Energy, Fuel Cells, MEMS and Nano technology.

Two student competitions were held simultaneously during the conference - CSME Undergraduate Student Design Competition and CSME Graduate Student Best Paper Competition. For the CSME Graduate Student Best Paper Competition, 81 eligible papers entered the competition. 10 finalists were selected by a review panel. Each of 10 finalists gave an oral presentation at the conference to the review panel, and 3 students received the best paper awards for the 2012 CSME Graduate Student Best Paper Competition. The 10 finalists were announced at the conference banquet and a plaque and a cash award were given to each of the top 3 recipients of the Best Paper Awards. For the CSME Undergraduate Student Design Competition, 4 universities sent the design teams participating the competition. The competition was based on the quality of the design reports and the oral presentations given during the conferences. The top three teams received the Design Awards, which were announced at the banquet. Each winning team received a plaque and a cash award.

report provided by Dr. Christine Wu

The 24th Canadian Congress of Applied Mechanics (CANCAM) Saskatoon, SK, Canada, June 2-6, 2013

The 24th Cannadian Congress of Applied Mechanics (CANCAM) will be held in Saskatoon, from June 2 to 6, 2013. The Department of Mechanical Engineering at University of Saskatchewan will host the meeting. This is the twenty-fourth in a series of biennial conferences that began in 1967 at l'Université Laval. The Congress provides an international forum for communicating the most recent advances in the field of Applied Mechanics.

The conference covers all areas of applied mechanics, including:

- Dynamics • kinematics •Vibrations
- Fluid Mechanics
- Thermodynamics
- Heat and Mass Transfer
- Mechanics of Solids and Structures
- Computational Mechanics
- Biomechanics
- Manufacturing Systems
- Materials Science
- Mechatronics
- Education in Applied Mechanics
- History and Philosophy of Mechanics
- Emerging Fields

For details of the congress please check the home page of the conference:
http://spencer.usask.ca/affiliation/cancam2013/index.html

Call For CSME Awards Nominations

CALL FOR CSME AWARDS NOMINATIONS

Nominations are solicited for the 2013 awards and honours of the Canadian Society for Mechanical Engineering (CSME), which aim to recognize and honour deserving members of the Society and the mechanical engineering community.

Honours and Awards

1. The **I. W. Smith Award** was established in 1977 to honour Professor I. W. Smith who devoted a lifetime to teaching mechanical engineering at the University of Toronto. It is awarded annually for outstanding achievement in creative mechanical engineering within 10 years of graduation.
2. The **G.H. Duggan Medal** was established in 1935 to honour Dr. G.H. Duggan who was president of the EIC in 1916. It is awarded annually for the best paper dealing with the use of advanced materials for structural or mechanical purposes. (revised 1983)
3. The **Robert W. Angus Medal** was established in 1957 to honour the late Robert W. Angus who was for many years Professor of Mechanical Engineering at the University of Toronto. It is awarded annually to a Canadian engineer for outstanding contributions to the management and practice of mechanical engineering. (revised 1993)
4. The **Jules Stachiewicz Medal** was established in 1983 to honour the late Jules Stachiewicz who was for many years Professor of Mechanical Engineering at McGill University. It is awarded alternately by the Canadian Society for Chemical Engineering (CSCE) and CSME for outstanding contributions to heat transfer in Canada.
5. The **C.N. Downing Award** may be presented annually to a member of the Society for distinguished service to CSME over many years.
6. The **Andrew H. Wilson History Award** was established in 2008 to recognize the contributions to this field of a past-president of CSME and longtime chair of its History Committee. It may be awarded annually for contributions by a member of the Society to the history of engineering.
7. The title, **Fellow of the CSME**, may be awarded to members, in good standing, with uninterrupted membership in the society for at least 3 years, who have attained excellence in mechanical engineering and who have contributed actively to the progress of their profession and of society.
8. A **Certificate of Service** may be awarded to CSME members in recognition of outstanding service to the Society in a particular capacity.
9. The **President's Award** was created in 2004 to honour individuals for their exceptional service to CSME and to mechanical engineering in Canada. It is awarded at the discretion of the President and Board of Directors.

Nominations

Nominations should be sent to the Chair of the HAF Committee, so as to reach by **January 31, 2013**, at:

Chair, Honours and Awards Committee
Canadian Society for Mechanical Engineering
1295 Hwy 2 East
Kingston ON K7L 4V1, Canada
Email: csme@cogeco.ca
Tel: (613) 547-5989 Fax: (613) 547-0195

The nomination package should consist of:

a. The nominee's name, occupation, position, title, affiliation, CSME membership number, and full address and contact information (including telephone, email, fax).

b. The nominee's CV.

c. A nomination letter from the nominator indicating the nominee's principal contributions and the reasons the nominee merits the award.

d. A draft citation for the nominee (125-150 words), which is intended for use in announcing the award recipient and publicity should the nomination be successful.

e. The nominator's name, position, title, affiliation and full address and contact information (including telephone, email, fax).

f. Two letters of support for the nomination, along with the names and addresses of the two supporters (including telephone, email, fax).

The CSME would like to acknowledge the support from the following ME Departments
La SCGM tient à remercier les départements de génie mécanique suivants pour leur aide

UNIVERSITY OF ALBERTA
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