DESIGN OF TANDEM FOR CEREBRAL PALSY SUFFERER

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ABSTRACT
This paper outlines, through a specific design commission ***'the design and realisation of a 'one off' tandem to aid the development of an adolescent male who suffers from cerebral palsy',*** methods of curriculum development being undertaken at Nottingham Trent within the restructured subject area of Product Design**.** The design is being undertaken by students on programmes of study leading to;
1. BSc Honours Degree Product Design (years 1 and 2), and
2. BSc Honours Degree Mechanical Engineering, final year.

The design supervision is undertaken by the programme leaders for the courses mentioned who are principal lectures in engineering design and product design and have conducted research in the field of inclusive design for the past 15 years. The integrity of the design work is underpinned by the experience and knowledge of the designers, the evidence for which can be demonstrated through published papers and extant products developed and realised in this particular field. It was anticipated that reporting of two areas of particular interest would be forthcoming from the work; namely,
- Pedagogic issues of students working in groups across different levels of HE and different disciplines, and
- Design for Manufacturing issues relative to the use of new techniques i.e. CAD/CAM in particular laser cutting and jig and tool development.

The authors intend to use the experience gathered to introduce more innovative teaching and learning methods to the subject area post 2007. The authors also acknowledge a grant of £400 from Radcliffe-on-Trent Lions, to aid with the design and build of the tandem.

Keywords: Cerebral Palsy, Inclusive Design, Pedagogic methods.

1 INTRODUCTION

This paper describes the design activities undertaken by students at Nottingham Trent University studying for degrees at honours level in either Mechanical Engineering or Product Design. The design activity encompassed the concept design, development and build of a tricycle tandem, bespoke by nature, for a teenage sufferer of cerebral palsy. Originally the 'running frames' and 'tricycles' of this type were designed to enable cerebral palsied athletes, of school age, to participate in sporting activities. The use of muscle power greatly enhances the quality of life for the cerebral palsy athlete and various devices and toys have been designed for this purpose since 1968. 'In many of these cases it is healthy to exercise the useless-seeming limbs. The vehicles were designed so that they can be operated with one or more limbs; the rest are exercised in the process' [1]. The key issue for the cerebral palsy sufferer is one of independence. This particular 'tandem tricycle' is required by a teenage cerebral palsy sufferer, who has limited use of his limbs but enjoys the sensation of 'freedom', cycling can give. The objectives of the project and the resulting commentary will be based on the following eight criteria; 1) Inclusive Design; 2) Anthropometrics; the ability to feel, strengths, etc.; 3) Design Methodologies; 4) Research Methodologies; 5) Pedagogic research relative to the study of design: how students and people interact with people with cerebral palsy; 6) Materials Design; strength of materials and joints; 7) Design for Manufacture, (DFM); 8) Sustainable Design. It is envisaged that students leave the university with a legacy of acceptable designs and the knowledge the programme itself is valid, they leave as broadly educated people with the flexible, technical and social skills to pursue a worthwhile career and be able to tap into at any future point another programme of life long learning. Therefore, before commencing with the design activity the students were reminded of the medical conditions surrounding cerebral palsy, namely; the control of muscles, difficulty with walking, writing, etc; problems with balance and coordination; difficulty controlling and maintaining posture; visual difficulties ; hearing problems ; learning difficulties; epilepsy (this affects as many as one in three children with CP). These problems are caused by one of the three main types of cerebral palsy, that is one, Spastic cerebral palsy where some of the muscles in the body are tight, stiff and weak, especially when the person tries to use them, making control of movement difficult; or two, Athetoid cerebral palsy where control of muscles is disrupted by spontaneous and unwanted movements making control of posture difficult and also disrupted; and three, Ataxic cerebral palsy where problems include difficulty with balance, shaky movements of hands or feet, and difficulty with speech. There is no cure for cerebral palsy; none of the sciences has yet developed a way to repair damage to the brain. However, there are plenty of treatments and therapies that can reduce the impact of the condition, by easing symptoms such as spasticity, improving communication skills or finding other ways to do things i.e. substitution. Physiotherapy, occupational therapy and speech therapy can all play an important part.

2 PEDAGOGIC METHODS

The programmes which form the Product Design suite of courses have been extensively re-written, 2005-2006, influenced by directives from the Higher Education Funding Council for England, associated professional bodies and the teaching team's own thoughts on design teaching. Not only have the programmes been re-specified and re-written but the academic year has been re-designed to give the students a new dynamic and more rewarding experience. The academic year, of thirty weeks (1-30), is currently divided into five teaching blocks of one (week 2), six (weeks 4-9), three (weeks 12-14), five (weeks 16-20) and five week (22-26) durations, for discipline specific teaching based around, lectures, seminars, studios and small group tutorials. There are six, one week school activity sessions, week 1 induction, week 3 design week, week 10 assessment, week 11 guest lectures, week15 networking, week 21 guest lecture and the final four weeks of term are set aside for the final year Design Exposition, and first and second year assessment by portfolio and critical presentation. The final four week period is also taken as an opportunity to prepare students for level three by calling back those on placement for their industrial/commercial assessment. Both first and second year students who were studying on the BSc Honours programme in Product Design undertook this design exercise during 'design week'. This is a week in the academic year when, if possible, students are encouraged to work together on one brief in a compacted time space. They have the opportunity to work with different levels and different disciplines in small self organised groups, aligning with peers whose expertise they can use to bring a given brief to fruition. This activity resulted in seven workable concept designs ready for consideration to be weighted against the given design brief. The project was now offered to a group of second year product design students, (Massey, Ryan, Pitts and Miller) and final year engineering students (Bendry, Fong, Worters, Roche and Vincent); hopefully the blend would produce a design, fit for inclusion and manufacture, which could be built by the first week of May 2007. It was assumed the aesthetics would be covered by the product design students and the mechanics, stress analysis and mathematics would be undertaken by the mechanical engineering students, however although this proved not to be the case, all aspects of the design and build were successfully undertaken.

3 DESIGN BRIEF

Armed with these facts and the activity week devised concepts the students were introduced to the teenager and his parents, who after analysing all the designs produced during the activity week formulated the following product design specification: currently a tandem tricycle is required by a cerebral palsy sufferer, who has limited use of his limbs but enjoys the sensation of ‘freedom’, cycling can give, to that end the design specification has the following criterion: 1) design a tandem tricycle such that the rear cyclist sits in the normal position but the front cyclist adopts a recumbent position; 2) the rear cyclist can view over the front cyclist; 3) the rear cyclist steers; 4) the rear wheels are standard 26 inch diameter; 5) the rear axle incorporates gearing to move two people with a combined weight of 24 stones i.e. 152.73 kg. 6) the rear axle has some form of differential gearing to control the rear wheel velocities; 7) the front wheel is to be a standard 16 inch set up; 8) consideration is given to the centre of gravity of both riders; 9) the frame to be open, allowing independent access; 10) design a chassis to increase frame stability; 11) re-design the steering geometry making it easier to steer; and 12) reduce if possible production costs and build in sustainability and re-cycling of components.

4 CONCEPT DEVELOPMENT

The students now concentrated on various elements of the total design process and followed a methodology of total design as put forward by Pugh [2]. It was decided to build a tandem tricycle with the front 16 inch wheel the extremity of the wheel-base, as shown by figure 1. This design feature requires careful consideration for the following reason; the ability of a cycle to ‘steer’ under reasonable effort yet still afford the user the ease of a self centering effect is determined by ‘steering geometry’, [3]. The most important of the three parameters relative to the steering geometry is the ‘trail’, figure 2, since this sets the mode i.e. a large value sets a straight course but requires a large force to round a corner, whereas a small value requires such little effort it is difficult to maintain a straight course when required. Van den Plas [4] suggested trails of 65mm for touring, 50mm for racing, taking into account such variables as wheel size, maximum speed etc. However, Sharp [5] suggested the following relationship: $P = R \cos \alpha - f \sin \alpha$; $E = P \sin \alpha$; where P = projected or actual trail, E = effective trail, R = wheel radius, f = fork rake, α = rake angle. Therefore, using a 20 inch wheel and accepting the optimum rake angle of 73.5^0 -74^0 as suggested by Van den Plas, an optimum trail of 38-40 mm was obtained.

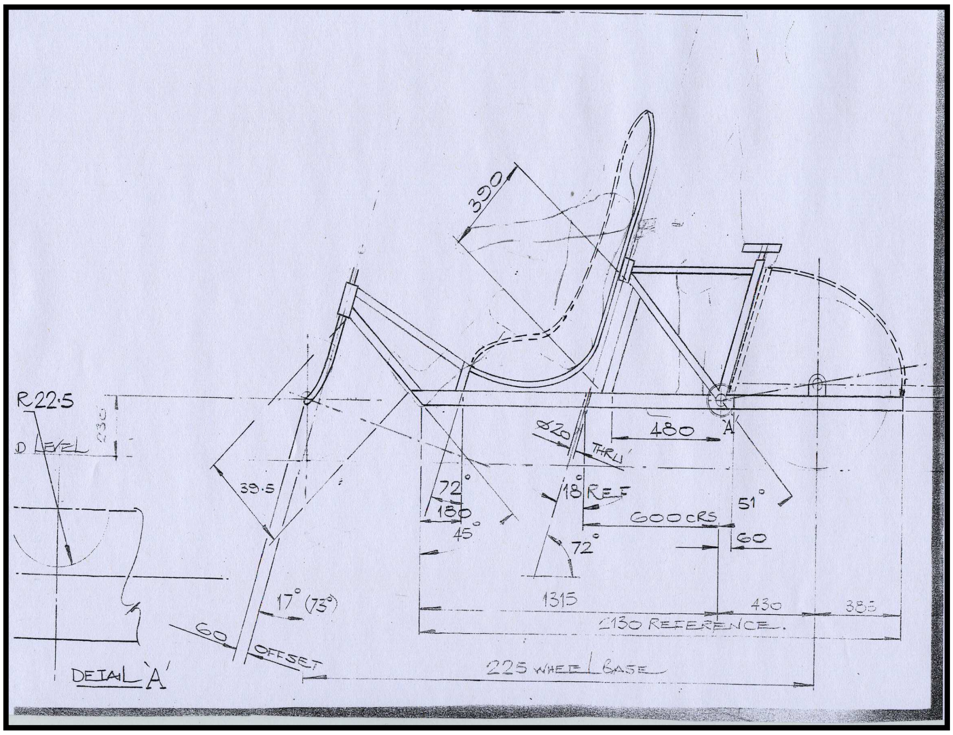

Figure 1 Layout of Tandem with Main Dimensions

The reasoning behind this choice lay in the research done on different configurations of vehicle wheel base. The wheelbase of a vehicle is the length between the rear wheel(s) axle and the front wheel(s) axle [6]. It is generally accepted that there is no perfect length for a vehicles wheelbase, however, differences in length can drastically reduce or improve performance characteristics.

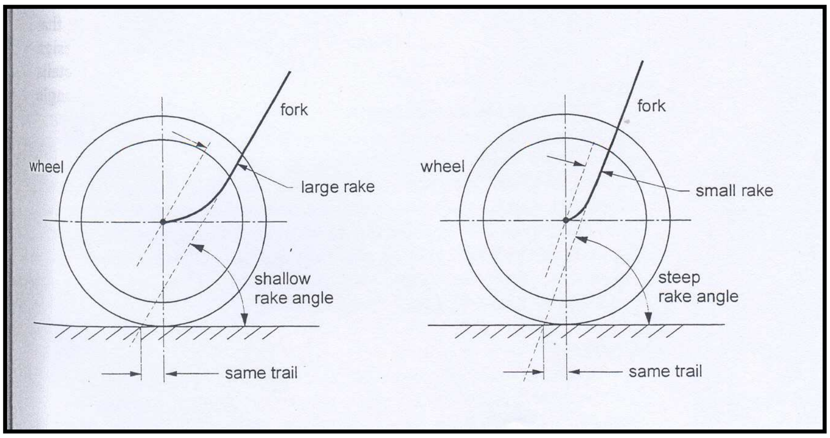

Figure 2 Steering Geometry

The design was broken into sub-assemblies by the programme tutors and interestingly the Product Design students did not choose to design purely from an aesthetic stance. It was also noted that they were more open in their approach to the design activity and to integrating Ashley into the process. They decided to design the rear axle assembly but on their own volition integrated fully with the engineering students by passing the orthographic design details to them for stress analysis. The bulk of the design work was carried out using Solid Works and the analysis done using ANSYS. The calculations to include braking force, gear stress and steering force were done by the engineering students, however not in isolation, and they reviewed constantly their progress with their peers from Product Design. However, they showed a reluctance to design by sketching, brain storming and 3 dimensional CAD work but confined themselves to a very structured and numerical approach, surprising since they are taught 3 dimensional CAD from year 1. Not only was there good integration between the students but a remarkable feature of this design project was the active part taken by the cerebral palsy sufferer and his parents, Barry and Lorraine, who fully co-operated with the students. Ashley and his parents took an ever increasing active role throughout the duration of the design development stage; acting as a single user group their contribution became invaluable, particularly with the Product Design students. The design of the seat for Ashley was undertaken by two students on Product Design second year, uniquely they used a second hand car seat to photograph Ashley in the seated position. The photographs were then utilised via Photoshop and Solid Works to develop a seat to match Ashley's anthropometric and ergonomic requirements.

Figure 3 Measurements

Figure 4 Ashley interactive with the design process

The project required the design and build of a double wheel back axle set, incorporating a differential gear box and four bearing support system for the derailleur gear block. Front wheels were used to allow the disc-mounting boss to accept the flange of the rear axle; it was extended through the wheel acting as a conventional stub axle, figure 5. The material for the axle and main stay of the chassis was chosen as 50mm x 25mm x 3mm wall thickness medium carbon steel, extruded and seamed, this gave good strength characteristics, machine-ability and more importantly excellent welding capability. The rear axle support column was bored to minimum edge distance dimensions to create a lighter structure without sacrificing strength, as shown by figure 6.

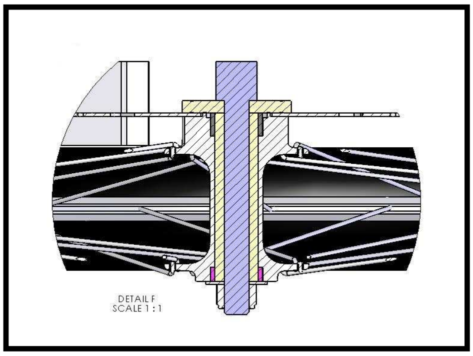

Figure 5 Stub axle

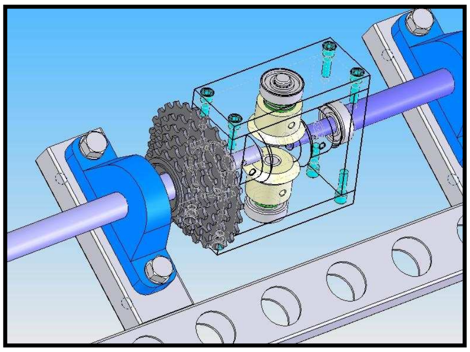

Figure 6 Rear axle assembly

Interestly, one major design problem, overcome by using old technology, the cotter pin, was the siting and fixing of the bottom bracket and cranks which Ashley would use at the front of the tricycle. Instead of designing an adjustable bracket, it was welded on site, with Ashley in situ', which was seen as excellent user integration, possible because no damage is incurred by the bracket, due to welding, if the crank fixing is by cotter pin and not by modern tapered section and plastic cups.

5 CONCLUSION

The final designs and prototypes match well the design expectations and detailed PDS. The products are delivered based upon genuine solutions from both a technical and social perspective. The collaboration among all participants, product designers, mechanical engineers and including the user, proved to be most effective in the development of the design. The tandem-trike can be genuinely built from recycled components with no requirement for high technology input. There has been true integration of the themes of sustainability and inclusive design; in particular greater awareness of the others' needs has been developed within the student cohort. It is also encouraging to rediscover 'old technology' to be of benefit to solve design problems in the 21st century, e.g., the humble cotter pin. The user, Ashley and his parents have benefited from the experience of integrated design activity. Ashley acknowledges it is his tandem and he and his parents have been an integral part of the design and manufacturing process, what more could academic and professional designers ask for?

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