Digital Braille Watch

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Abstract

The Braille system is the primary reading and writing method for 285 million visually impaired individuals worldwide[1], yet no device exists that utilizes Braille to display time. Currently, to check time the blind use talking or tactile watches, but talking watches are disruptive, while tactile watches are difficult to read and fragile. The final Braille watch prototype utilizes a gear, disk and pin mechanism to display time. Preliminary testing verified that this design was accurate and easy-to-read, and force analysis identified a motor for use within the watch. By making molds of the watch components, it was proven that this design could be mass-produced quickly and durably at low cost. The team has already submitted a patent application for the design and now aims to gain company interest and market the watch.

Background

Braille Basics[2]

- Method of written communication used by the visually impaired
- Numerical characters use a two-by-two grid
- Using different combinations of raised or lowered dots, all ten numbers can be displayed
- Size standards – dots at least 2.34 mm. apart, 0.48 mm. in height; characters 6.22 mm. apart

Braille Numerals (Figure 1)

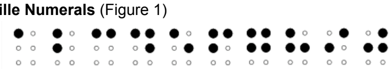

Figure 1: The Braille numbers 0-9 each consist of four dots

Design Criteria

Improve upon competition

- Talking watch – disruptive
- Tactile watch – fragile and difficult to read
- Several concept watches

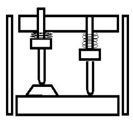

Figure 2: Fall 2010 design shows spring mechanism that keeps pins below watch surface

Create an innovative and functional Braille watch

- Size of a standard wristwatch
- Silent, accurate, reliable
- Standard Braille numbering and spacing
- Advance past designs (Figure 2,3)

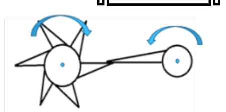

Figure 3: Spring 2011 design demonstrates how the gear system within the Braille watch leads to intermittent rotation of the disks

References

[1] "Visual Impairment and Blindness". World Health Organization. Apr. 2011. 26 Apr. 2011. http://www.who.int/media centre/factsheets/fs282/en/.

[2] "Size and Spacing of Braille Characters." Braille Authority of North America. n.d. 27 Jan. 2010. <http://www.Brailleauthority.org/sizespacingofBraille/>.

Final Design

Design Concept

- Four rotating disks are located beneath watch surface, one for each Braille digit (Figure 4)
- Each disk has raised and recessed surfaces, which raise and lower pins (Figure 5) creating desired number
- Disks interact via integrated gears
- Overlapping the disks allows for standard spacing
- Multi-compartment casing holds watch together

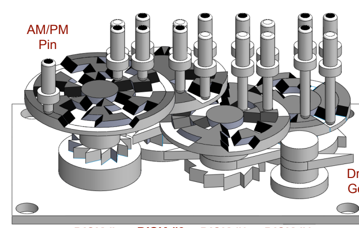

Figure 4: By designing four disks with the appropriate raised and lowered surfaces, pins can be correspondingly raised and lowered in order to display the correct time

Features

- 12-hour watch with AM/PM indicator pin (up = PM)
- Rotating the drive gear once per minute will control the entire watch (Figure 4)
- Standard Braille spacing
- Final dimensions = 35.636 x 23.393 x 17.805 mm. (length x width x height).

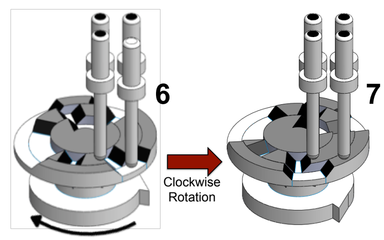

Figure 5: The raised and recessed surfaces on the disk cause the numbers 0-9 to be displayed as the disk rotates clockwise

Force Analysis

Calculations

- Modeled worse case scenario to determine τ_{max} needed at drive gear
- Considered 2 forces:
  - Force pin exerts on disk slopes (Figure 6)
  - Friction force between gears and casing
  - All other forces were modeled as negligible
- Modeling torque relationship between all disks/gears gave τ_{max} = 3.6×10^{-3}Nm (Figure 7)

Motor

- τ_{max} well within range of many micromotors
- Safety factor > 2
- Various manufacturers – Faulhaber, Audemars, etc.

$$\Sigma F_x: F_{app} = N\cos45° + F_p\cos45°$$

$$\Sigma F_y: (W + kx) + F_p\cos45° = N\cos45°$$

$$F_{app} = \frac{(W + kx)(1 + \mu_p)}{1 - \mu_p}$$

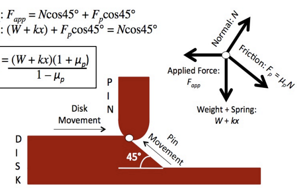

Figure 6: As the disk rotates, the pin applies a resisting force, *F_{app}, to the disk*

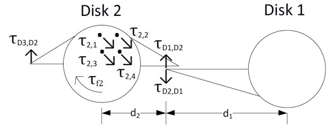

Figure 7: By modeling the torque each gear exerts on its neighboring gear, the maximum force required at the drive gear can be determined

Torque pin exerts on disk:

$$\tau_{Disk\#,Pin\#} = \frac{\rho_{pin} V_{pin} g + kx}{1 - \mu_p}(1 + \mu_p)(d)$$

ρ_{pin} = density of the pin (constant across all disks)

V_{pin} = volume of the pin (varies with given disk)

k = spring constant of springs holding pins in place

x = compression distance of spring

μ_p = friction between pin and disk

d = distance of pin from center of disk (varies with disk and pin)

Torque on disk due to friction:

$$\tau_{f,Disk\#} = \mu_c \frac{2}{3}\frac{r_{out}^3 - r_{inner}^3}{r_{out}^2 - r_{inner}^2}\left(n\left(\rho_{pin} V_{pin} g + kx\right) + \rho_{gear} V_{gear} g\right)$$

r_{out} = outer radius of base of gear shaft for given disk

r_{inner} = inner radius of base of gear shaft for given disk

n = number of pins for the given disk

Torque applied by gears:

$$\tau_{D1onD2} = \left(\tau_{2,1} + \tau_{2,2} + \tau_{2,3} + \tau_{2,4} + \tau_{f2} + \tau_{D3onD2}\right)$$

$$\tau_{D2onD1} = \frac{\left(\tau_{2,1} + \tau_{2,2} + \tau_{2,3} + \tau_{2,4} + \tau_{f2} + \tau_{D3onD2}\right)}{d_2}(d_1)$$

Manufacturing

Altering Design for Mass-Production

- Custom gear and disk piece re-designed for low cost mass-production
- Gears were broken into layers
- Axle component serves to align disk and gears (Figure 8)

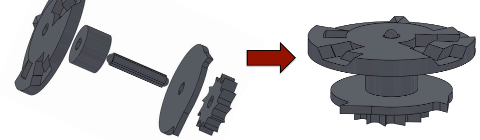

Figure 8: Re-designing the custom gear and disk component into multiple parts allows for easier mass-production

Molding Disks and Gears

- Molding provides low cost option for mass-production
- CNC milling used to produce disk master copy
- Viper si2 SLA printer used for remaining parts
- Mold produced with silicone and catalyst (melting temperature = 340°C)
- Casting performed using urethane and various metal alloys

Testing

- Volunteers from the Wisconsin School for the Visually Impaired provided feedback on the prototype
- Spacing was ideal, easy to read
- Could be marketed to military and elderly in addition to the blind
- SolidWorks animation verified design accuracy

Future Work

Mass-Production

- Brass-casted parts, cast iron molds
- Implement motor (Figure 9)

Cost Analysis

- Material cost - $0.06 for brass mold
- Motor cost – less than $15
- Manufacturing cost will continue to decrease with mass-production

Figure 9: A micromotor will be used to drive watch and must provide a minimum torque of 3.6×10^{-3}Nm

Marketing

- Patent pending, sponsored by Wisconsin Alumni Research Foundation
- Diverse market
- Technology has additional applications (elevator, low cost alternative to BrailleNote, etc.)

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