Veterinary Prosthetics

Consider a canine front double amputee (i.e., hind legs intact, but fore legs gone – humerus removed from the scapula). The owners of the dog would like it to achieve mobility and independence. In previous HW’s, a rough Engineering Design Specification has been developed, and a conceptual design has been selected. You may refer to these, or you may modify them as you think fit, to best inform the following assignment.

1. Embodiment Planning. Create a plan for the embodiment design of a selected overall concept. The plan may follow either the Dieter & Schmidt model or the Pahl & Beitz, or be some combination of these (cull the details important to your problem and concept from either plan – it isn’t necessary to include every possible step). The plan must be problem-specific (i.e., a line item of “module interface requirements” is insufficient; “suspension arm bushing axial and lateral stiffness” (assuming your concept has one of these) is more like it). Submit:
   a. Problem-specific embodiment steps
   b. Note specific instances of necessary attention to each of the three Rules
   c. Note specific instances of necessary attention to each of the six Principles
   d. Note specific instances of necessary attention to nine of the 21 Guidelines

Note: Ideas for better concepts are often generated by this process. For purposes of this HW, it is not necessary to follow up on those ideas. However, it would be useful to note and very briefly describe your ideas for concept improvement.

From the Concept Generation Solution Guide, Concept 3 (Climbing Wheel)

Embodiment Steps

Mostly by the Pahl & Beitz method, because of the probably small number of parts, and architecture driven by the form of the dog.

Product Architecture

1. Form-driving EC’s are:
   e. Stair-climbing (governs position of climbing wheel)
   f. Pitch stability under forward motion over rough terrain (governs position of ground wheel)
   g. Fit to dog under loads of:
      i. Axial bump (climbing wheel impact)


ii. Vertical bump (susension loads)

iii. Lateral load transfer (cornering – tries to twist the tray around the body)

2. Spatial constraints are:
   a. Little more than the dog’s width
   b. Little more than the dog’s length

3. Perform kinematic analysis of the mechanism functioning in stair-climbing to sort out the wheel size and placement

4. Perform vehicle dynamics analysis of dog running on rough surface to determine pitch-stability sensitivity to ground wheel size and wheelbase.

5. Perform field trials with variable ground wheel size and wheelbase to confirm and calibrate analysis.

6. Select wheel sizes and locations

7. Static analysis of wheel loads (under axial and vertical bump, and max cornering) on tray, to find reaction pressures on dog skeleton; resolve to bearing pressure; review veterinary literature to set bearing pressure limits and arrange pressure points on tray.

8. Create three overall layouts
   a. One with trailing arms as shown in the initial concept drawing
   b. One with an alternate suspension arrangement based on lateral arms
   c. One with additional wheels and/or suspension arms, so that the loads on the tray are reduced

9. Through ride and lateral load transfer analysis, determine suitable values for suspension spring and damping. Include spring/damper devices in each layout

10. In each layout, include means for varying dog size

11. For each layout, determine the number of models necessary to cover the necessary range of dog sizes

12. Quantitative selection of product architecture

13. Consideration of improvement of layout/concept

14. Failure Modes and Effects Analysis, with design corrective

15. Prepare Bill of Materials, with build/buy decision for each part

16. Final Product Architecture drawing

Configuration Design

1. Part configurations for:
   a. Suspension arms
   b. Wheels
   c. Tray & Straps
   d. Structure to attach climbing wheel axis to tray

2. Including:
   a. Forces, stresses, degrees of freedom
   b. Material selection
   c. Pivot points & clearances (including shocks)
3. And incorporation into Product Architecture (overall arrangement)
4. FMEA
5. More detailed BOM
6. Functional analysis update v. EC’s (as design has changed a bit since last analysis)

Parametric Design
1. Detailed stress analysis and redesign for main parts
2. Cost estimate
3. Weight estimate
4. Manufacturing plan
5. DFX review and design update
6. Final embodiment overall and part drawings.

Rules
1. Clarity – location-fixing of the ground and climbing wheels with respect to the tray and dog will be key in this design
2. Simplicity – this is not a motor vehicle – it needs to be as simple and light as the dog’s function will allow
3. Safety – What is the failure chain that will lead to the tray rotating from the bottom to the top of the dog? How much does the dog have to over-sue the device before it abrades it’s skin under the tray?

Principles
1. Force transmission – take bending out of the suspension arms (load in tension/compression)
2. Division of tasks – separate spring and damping values in the shock arrangement
3. Self-help – rotation of tray about dog should tighten the attachment, not loosen it
4. Stability – pivot points mounts are not worn out by the pivot pins
5. Bi-stability – what happens if the dog pushes the climbing wheel into an obstacle that is too high? No-function, or disaster?
6. Fault-free – a natural here is fit and function over the whole range of dog size/shape

Guidelines
1. Creep – loosening of fit over a day of dog activity
2. Corrosion – OK, this is material selection. Design to avoid uniform atmospheric corrosion (a dog will go anywhere)
3. Wear – motion abrasion on the humerus contacts
4. Ergonomics – stretch and motion of the dog’s body as it runs, with associated flexibility in the tray
5. Aesthetics – looks like a dog with a prosthesis, not a dog in the grips of an evil robot
6. Production – well, of course – how are you going to make it? Can you make it more easily (material and labor effectively)
7. Assembly – also of course. DFMA.
8. Industrial standards – check in with Vet Med industry
9. Distribution – try to keep the number of sizes down.