Department of Mechanical and Mechatronics Engineering

Equilibrium **ME219 – Mechanics of Deformable Solids 1** **Case Study 1**

A group of fourth year engineering students[1], calling themselves *Joint Effort*, set out to design and verify a loading device which would apply a compressive force to a person's wrist during an MRI (Magnetic Resonance Imaging) scan. The MRI scan was used to detect damage to the wrist; research had suggested that it was sometimes useful to put the joint of interest under load to better image the damaged area. No such device existed, and their plan was to design and verify the function of the device, and then to publish their detailed results to benefit the medical community. MRI devices are designed to image the whole body, Figure 1. However, smaller auxiliary devices are available to obtain better resolution images of extremities. Figure 2 illustrates one such device in use.

Figure 1: Example MRI machine

Their solution consisted of a stiff loading base which held the arm in position and reacts any forces, while allowing for an elastic resistance band to apply a load to the wrist, Figure 3. The patient's arm was secured to the base using Velcro straps, and the band was held within the patient's fist and tensioned

[1] Kelly Hao, Michael Beals, and Catherine Zhang

Based on "MR Compatible Wrist Loading Device", Kelly Hao, Michael Beals, and Catherine Tsang, ME482 W21.

using a hook machined into the base, Figure 4. Their base was designed to readily convert for left and right-arm operation, Figure 5.

Figure 2 Typical upper extremity auxiliary coil

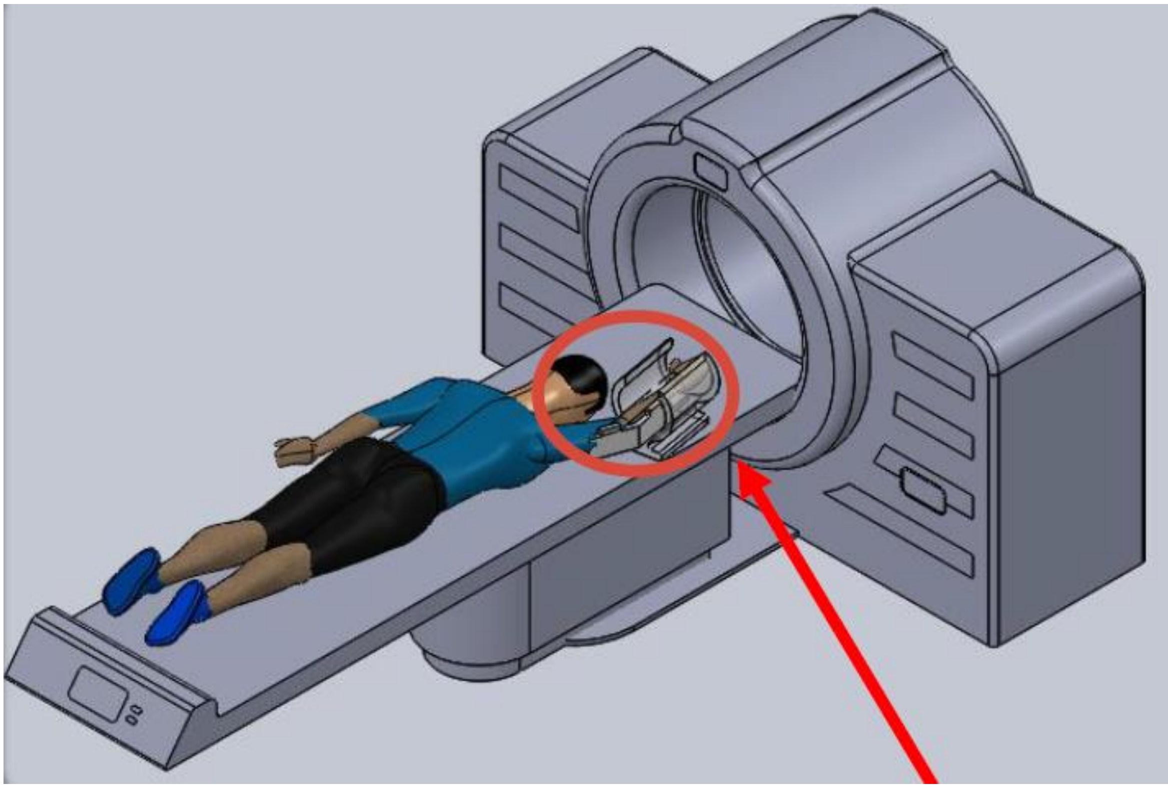

Figure 3: Overview of the final device within the MRI environment.

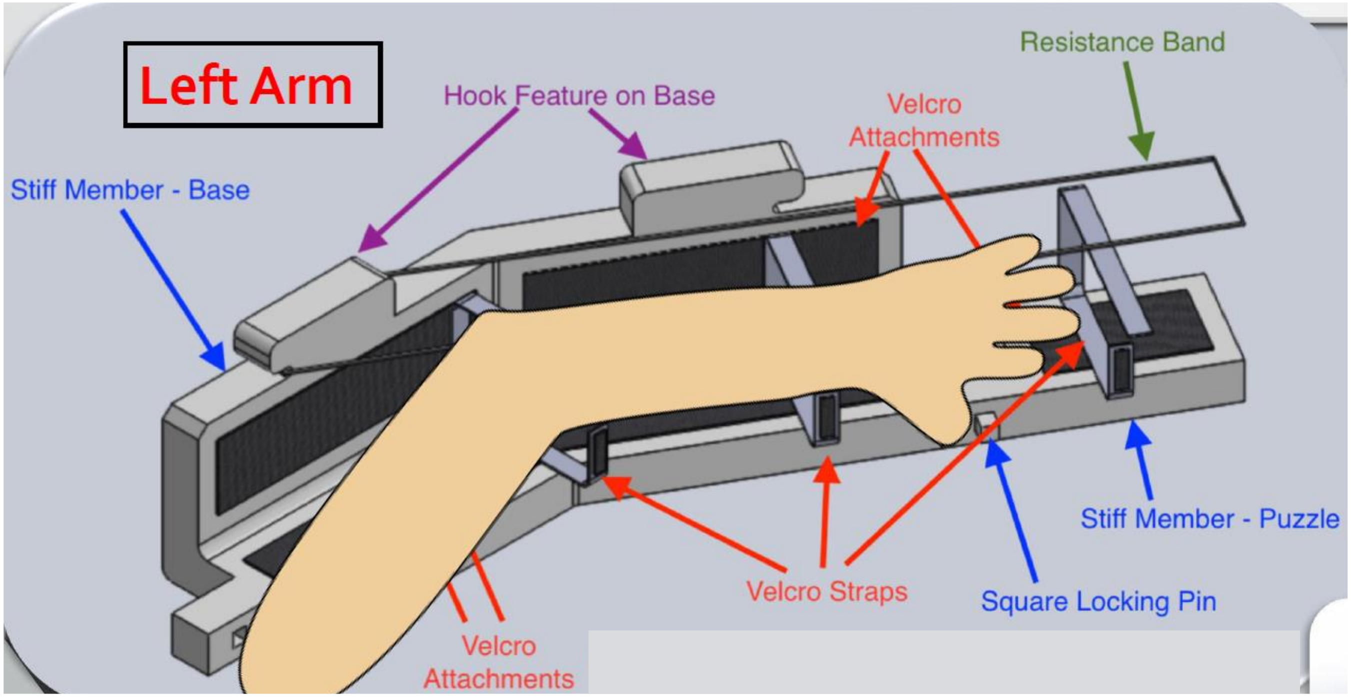

Figure 4: Overview of loading device

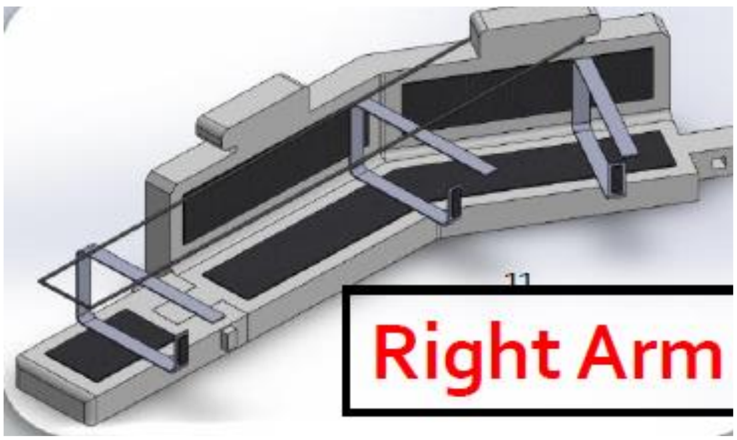

Figure 5: Loading device configured for the right arm.

Based on discussions with MRI technicians, they determined that the required compressive load to the arm was between *5* and *10 lbs* (*22* to *44 N*). Further, the maximum moment that should be applied to the wrist during loading was *2 N·m* to ensure the comfort of the patient for typical *10-15 minute* exposures. They created a proof-of-concept prototype to further examine the loading geometry, Figure 6. Figure 7 illustrates a close-up of the wrist and loading band. Based on avoiding interference with both the patient's arm and the MRI coil, they determined that the angle of the band from the horizontal, θ, should be between *5°* and *30°*.

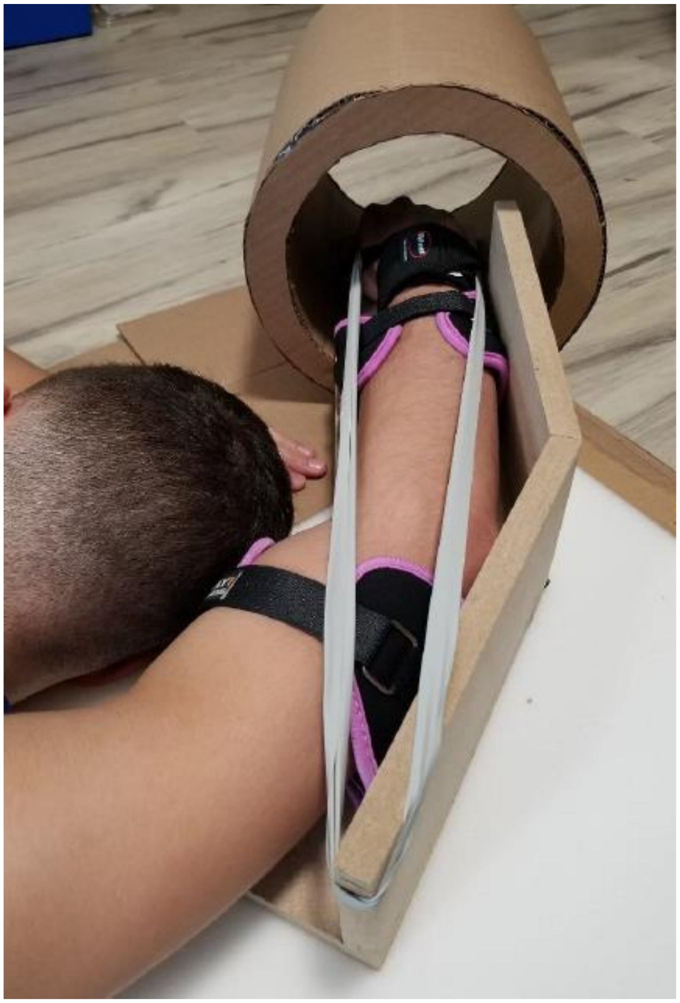

Figure 6: Proof-of-concept prototype with MRI auxiliary coil mock-up.

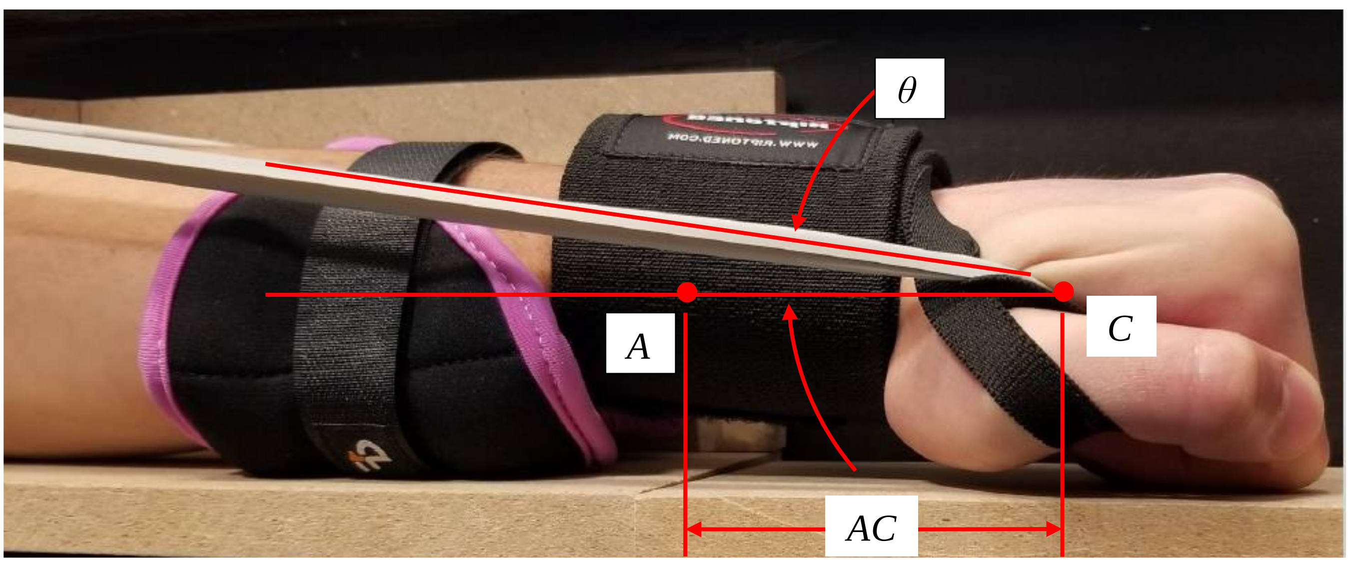

Figure 7: Side view of wrist and loading band.

They sought to accommodate the widest range of potential users. In practice, it is impossible to accommodate everyone, so representative smallest and largest members of a target audience are identified. It is common to use the 5th percentile[2] female and the 95th percentile[3] male as the limits. In Figure 7, the centre of rotation for the wrist, point ***A***, is highlighted, along with the centre of the wrist, where the load from the elastic band is applied, point ***C***. Based on an examination of ergonometric data, they determined that this distance, ***AC***, was *59 mm* for the 5% percentile female, and *78 mm* for the *95th* percentile male.

Joint Effort needed to finalize the configuration of their device by selecting the specific hook location and choosing a specific resistance band.

[2] 5% of the target population will be **smaller** than this
[3] 5% of the target population will be **larger** than this

Case Study Solution Procedure

A case study is a description of a realistic situation which ends with a general problem statement. It provides the context for the problem as well as key data (but not necessarily all data) required for its solution. The intention is that you put yourself in the protagonist's position, the members of *Joint Effort* in this case, and proceed to a solution. Note that engineering design problems seldom have a unique solution, or even solution procedure, so this enables you to gain experience dealing with uncertainty and making reasoned decisions.

Although there is some variation in how a particular case solution is carried out, the following general steps should be useful.

1. **First, understand the problem.** Spend some time reading the case study and familiarizing yourself with the situation. Note down the key information provided, and clarify what is required. Do this individually, and then discuss in your learning group (in class).
2. **Restate the problem.** Once you have discussed the problem in your learning group, draw a sketch(s) to clearly indicate the situation. For our course, this will typically include the drawing of one or more **free body diagrams**. Identify all data provided, including their ranges as appropriate, and **indicate any missing data**. Clearly state what is required, **the key assumptions** that are required (some of these will only be apparent later as you proceed with the solution), and what characterizes a successful outcome for the case.
3. **Decide on a solution strategy**. In some cases, a simple calculation is required. Identify the key principle (ex., equilibrium) and the appropriate form of the equation. In other cases, you will be required to perform a sequence of calculations, or a sensitivity study[4], to identify the final recommended solution.
4. **Perform the analyses**. These should almost always start with a hand calculation, perhaps followed by a spreadsheet (or Matlab) calculation and/or computer simulation. Be sure to present your key results in a clear fashion, usually with a table and graph. It is much easier to see trends if you **plot your results**. Make sure you check your answers in some way, typically by having other group members go through the calculations.
5. **Present your results**. Prepare to concisely present your results, justify your assumptions, design choices, and final answer(s).

[4] A sensitivity study varies key input (design) parameters to examine their influence on intermediate or final results. In what direction should the parameter be changed to improve the results? Is there an 'optimum' value for the parameter to get the 'best' result?