What

We propose a method to test the Macro-Fiber composites (MFC) power output thanks to a mechanical framework specifically designed to replicate the kinematic of a knee joint and actuated using recorded human motion patterns.

Kinetic human energy harvesting is a way to power these components reducing the need for batteries replacement since walking or running is how humans already expend much of their daily energy.

Motor control input: human motion data from the Carnegie Mellon University motion capture database (1) a free dataset of motions recorded by means of a marker-based motion capture system. We fused and extracted the knee flexion position data to control the motor. Why the knee: the knee is a very important joint for energy harvesting purpose due to motion amplitude (120° + extra range of 40°) to the imposed force and frequency of use.

Experimental setup

• Harvesting: P2-type MFC piezoelectric patch (12) attached to a mechanical structure purposely-built to reproduce human joints motion approaching one degree of freedom.
• Actuating and sensing: Maxon motor modular system composed of a DC brushed motor and an encoder to monitor the patch bending-angle.
• Controlling: ARM microcontroller board along with the motor driver and an ADC to acquire the MFC’s power output.

Experimental results

Energy transfer efficiency: The efficiency is the power transferred into the electric load related to the total power in the source as a function of the resistors. Since the inner impedance of the piezoelectric patch is fixed, to optimize the power transfer from the power source into the electric load, we tested sixteen different resistances with a run/jog activity (1.29Hz, 83.5°) system input.

\[ \eta = \frac{P_{out}}{P_{in}} = \frac{R_{out}}{R_{in}+R_{out}} \]

Optimal load value (R = 470 KΩ)

Results and Discussion

Output signals: voltage drop across the optimum resistance and angular position are measured simultaneously in order to correlate the output power with the angular position of the joint. There is an almost monotonic dependency on the motion amplitude, the bigger it is the bigger the power output is and, when the movement range is over 100°, there is a power output boost of one order of magnitude. Instead, the frequency is not very influencing and the higher frequencies did not generate the bigger amount of energy.

• The maximum power output is from the nineth subject knees associated to the run activity at 1.35Hz frequency with 115° motion amplitude, we obtained 2.6 µW,
• By employing two MFC flexible patches per knee, one in the front and one on the back of the joints, it results about 10.4 µW output power that can be temporarily accumulated in a storage system (battery or capacitor);

<table>
<thead>
<tr>
<th>Subject</th>
<th>Action</th>
<th>Amplitude (deg)</th>
<th>Frequency (Hz)</th>
<th>Voltage (V)</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.60_L</td>
<td>Front</td>
<td>120</td>
<td>1.0</td>
<td>0.54</td>
<td>0.66</td>
</tr>
<tr>
<td>09.60_L</td>
<td>Back</td>
<td>120</td>
<td>1.0</td>
<td>0.54</td>
<td>0.66</td>
</tr>
<tr>
<td>09.60_L</td>
<td>Front</td>
<td>100</td>
<td>1.5</td>
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<td>Back</td>
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</tr>
</tbody>
</table>

Conclusion and Future Work

Future developments will focus on the wearable assessment in order to evaluate harvestable energy from different human activities (non-periodic) along with the development of an ultra-low-power sensing system for human motion detection.