Brew It Yourself

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Motivation

The traditional method for homebrewing requires various components, constant monitoring and heavy maintenance. There should be a solution which reduces complexity, making it much more affordable and practical for home use. The hope is to create a single vessel system that would make the home brewing process precise, automated and compact, all at a reasonable price.

Objective

Combine homebrewing experience with engineering design, and construct a single vessel brewing system. By maintaining a strict control of key parameters, the brewing process is regulated using a combination of fluid mechanics, heat transfer, digital controls, power systems, embedded robotics and mobile development.

Block Diagram

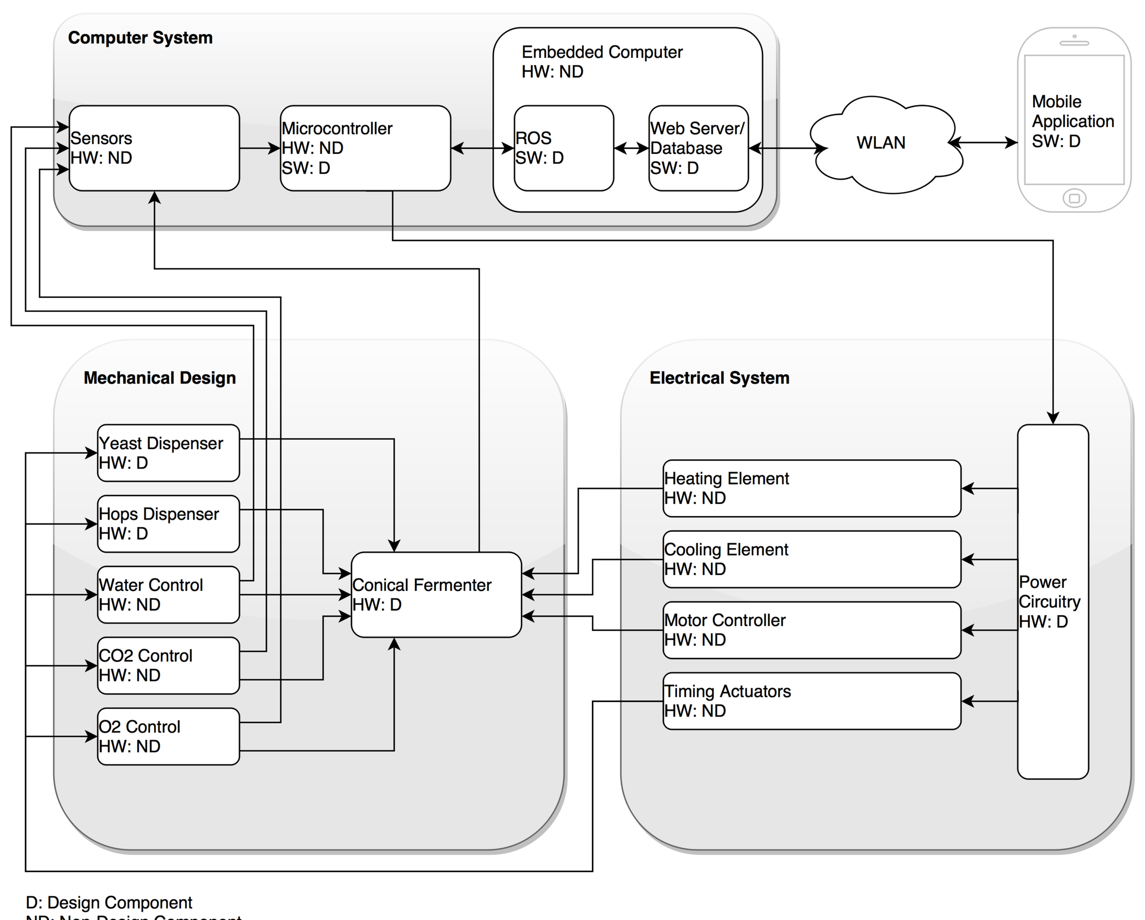

Figure 1: Mechanical, electrical, and computer system interactions

References

[1] J. Palmer, ``Skip the sparge!,'' 2002. http://byo.com/malt/item/1375-skip-the-sparge. [Accessed 2015-12-03].

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Mechanical System

The American Society of Mechanical Engineers (ASME) outlines a function for determining the wall thickness of a pressure vessel as:

$$t = \frac{P_{work} \times r \times FS}{\sigma_{uts} \times E} \tag{1}$$

Therefore:

$$t = \frac{206.84kpa \times 254mm \times 9}{505MPa \times 0.6} \tag{2}$$

$$t = 1.560mm \tag{3}$$

The maximum stress experienced by the collar of the outer tank occurs at the inner edge of the collar.

$$\sigma = \frac{3w}{mt^2(a^2-b^2)}\left(a^4(3m+1)+b^4(m-1)-4ma^2b^2-4(m+1)a^2b^2\ln(\frac{a}{b})\right) \tag{4}$$

Therefore:

$$t^2 = \frac{3w}{m\sigma(a^2-b^2)}\left(a^4(3m+1)+b^4(m-1)-4ma^2b^2-4(m+1)a^2b^2\ln(\frac{a}{b})\right) \tag{5}$$

The resultant thickness is 2.05mm, or 0.08in. Accounting for a safety factor, a sheet thickness of 0.125in. was selected.

Figure 2: A mechanical render of the full vessel

Brewing Theory

The brewing process consists of heating the grains in water to extract the sugars and other flavors (mashing), removing the spent grains but forcing boiling water through them to extract the last sugars (sparging), this sweet water (called wort) is then boiled for sterilization, adding yeast to begin the conversion of the sugars to alcohol (fermentation) and finally treating the product. During the boiling process, the flower of the hops plant is added for preservation, and to add a bitter flavor.

Electrical System

Since the temperature model of the main volume of water is the same regardless of temperature change; the cooling system is identical to the heating system with respect to power.

$$Qh = Qs + Ql \tag{6}$$

If differentiated with respect to time, the result is Equation 7.

$$P = C \times \frac{dT}{dt} + k(T - T_a) \tag{7}$$

Taking the Laplace transform of both side, results in Equation 8.

$$P(s) = C \times s \times T(s) + kT(s) \tag{8}$$

Resulting in Equation 9, the transfer function model of the heating of a volume of liquid.

$$\frac{T(s)}{P(s)} = \frac{1}{Cs + k} \tag{9}$$

Finding the value of the parameter C is relatively straightforward, it is equal to the mass of water in the system multiplied by the specific heat capacity of water.

$$C = 50L \times 1\frac{kg}{L} \times 4200\frac{J}{kgK} = 210,000\frac{J}{K} \tag{10}$$

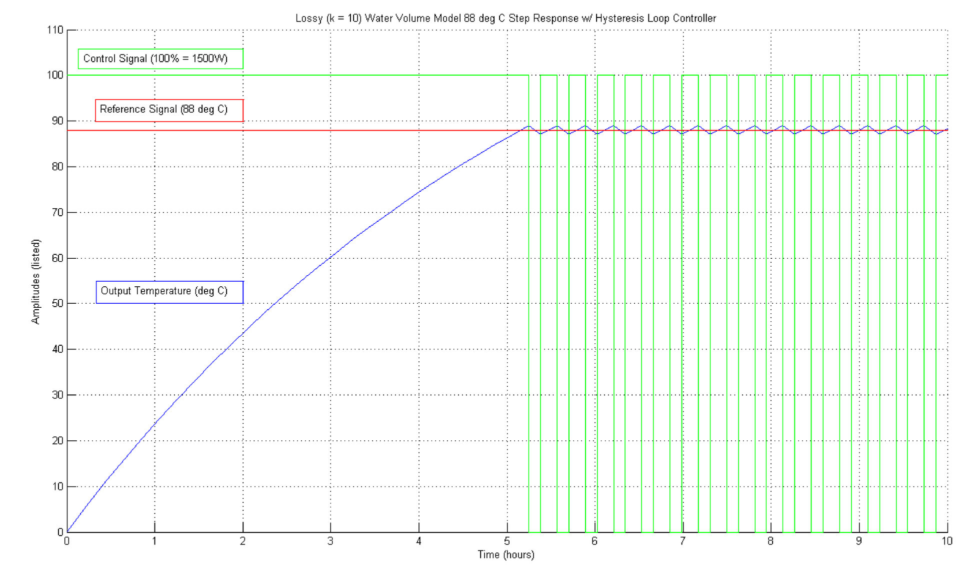

Figure 3: Lossy hysteresis loop step response with control signal

No Sparge Algorithm

The no-sparge technique uses 25% more grain and allows for the sparging process to be bypassed with no ill effects. This process greatly reduces the complexity of the process/system and makes the wort more robust and pH stable [1].
The scale up factor is calculated by using Equation 11.

$$S = \frac{V_b}{(V_b - kG_r)} \tag{11}$$

The no-sparge grain-bill is calculated using Equation 12.

$$G_n = S \times G_r \tag{12}$$

The no-sparge boil gravity is adjusted by using Equation 13.

$$BG = OG \times \frac{V_r}{V_b} \tag{13}$$

The total no-sparge water volume in quarts is determined by Equation 14.

$$W_n = 4(V_b + kG_n) \tag{14}$$

By using Equation 15 the no-sparge mash ratio is calculated.

$$R_n = \frac{W_n}{G_n} \tag{15}$$

The volume of water used for the mash-out in quarts is determined by Equation 16.

$$W_{mo} = G_n(R_n - R_r) \tag{16}$$

Finally, the total no-sparge mash volume in quarts is calculated using Equation 17.

$$V_t = G_n(1.3125 + (R_n - 1)) \tag{17}$$

Additional Information

Figure 4: github.com/BrewItYourself

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