WHOLE MILK FOULING OF HEATED SURFACES

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ABSTRACT

Whole milk fouling of surfaces within dairy products processing plants, especially that which occurs on heat treatment equipment, is an important operating problem, threatening the quality of product and reducing thermal and mechanical efficiency of equipment.

A fouling monitoring system was developed using a commercial heat flux probe and temperature sensor. The fouling monitor was installed in two unit operations of a custom built milk powder pilot plant. The unit operations replicated heat treatments found in plate heat exchangers and falling film evaporators. The research plate heat exchanger consisted of six miniature plate heat exchangers or modules in series. Individual modules could be isolated at any point during a run allowing access to the fouling deposit. The research falling film evaporator was a flat plate attached to a steam chamber and milk weir box. The onset and build-up of whole milk fouling on the evaporator plate was viewed through a sight window installed in the evaporator casing.

Trials conducted with the research plate heat exchanger showed that the monitoring system could detect whole milk fouling in terms of a reduction in the overall heat transfer coefficient. This reduction was shown to directly correspond to an increase in fouling deposit thickness.

For the same bulk milk temperature, the fouling rate decreased significantly when the surface was unheated compared with heated surfaces. This observation lead to a set of experiments that manipulated the start up procedure on both the milk and heating medium side of the research plate heat exchanger. More fouling was observed on plates after air start up (on the milk side) than on plates after water start up. Similarly, Surface Conditioning by Operational Protocol (SCOP) extended the fouling induction period. The SCOP trials compared steady state heating with unsteady state heating during start-up. Similar amounts of fouling were observed on plates removed from the steady state heated modules after 30 minutes and on plates removed from the unsteady state modules after 9 hours. These results indicate that the state of the stainless steel surface when the milk first makes contact has an important effect on the *subsequent rate of fouling. It is recommended that future work aims to identify which milk components deposit first onto the surface and what influence they have on inhibiting or facilitating fouling.*

The fouling monitoring system successfully estimated the extent of fouling for all of the trials. Industry trials for the fouling monitoring system, particularly on heated surfaces are recommended. The system will allow local areas of intense fouling to be mapped within the processing plants. A number of recommendations are presented concerning future work associated with start up procedure manipulation, evaporator trials and seasonal variation trials.

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LIST OF UNIT ABBREVIATIONS

Unit Abbreviation	Definition
°	degrees
°C	degrees Celsius
h	hour
Hz	hertz
K	Kelvin
kPa	kiloPascal
kW	kilowatt
l	litre
m	metre
mm	millimetre
mV	millivolt
s	second
V	volt
W	watt
w/w	weight/weight

LIST OF ABBREVIATIONS

Abbreviation	Definition
β-lg	beta-lactoglobulin
BSP	British standard pipe
CIP	clean in place
COD	chemical oxygen demand
CPU	central processing unit
DSI	direct steam injection
DTHE	double tube heat exchanger
HSSS	hot side steady state
HSUSS	hot side unsteady state
HTC	non-silicone heat transfer paste
HTS	silicone heat transfer paste
MPHE	miniature plate heat exchanger
NOHTC	normalised overall heat transfer coefficient
NZF	New Zealand Fasteners
OD	outer diameter
OHTC	overall heat transfer coefficient
PLC	programmable logic controller
PHE	plate heat exchanger
RFC	heated radial flow cell
RFFE	research falling film evaporator
RTD	resistance thermal device
TC	thermocouple
UHT	ultra-high-temperature

LIST OF SYMBOLS

Symbol	Definition	Units
λ	thermal conductivity	W/mK
χ	thickness of resistance layer	m
$\Delta\theta$	temperature difference	K
θ_0	temperature of process fluid	°C
θ_{100}	temperature of process fluid	°C
θ_c	calibrated temperature	°C
θ_p	temperature of process fluid	°C
θ_r	read temperature	°C
θ_s	temperature of heat flux sensor surface exposed to heating medium	°C
a	regression coefficient	
b	regression coefficient	
F	voltage multiplication factor (heat flux)	W/m^2
q	heat flux	W/m^2
R_a	heat transfer resistance of air	m^2K/W
R_c	heat transfer resistance of cement	m^2K/W
R_f	heat transfer resistance of fouling layer	m^2K/W
R_m	heat transfer resistance of milk	m^2K/W
R_p	heat transfer resistance of heat flux sensor	m^2K/W

LIST OF SYMBOLS (Cont)

Symbol	Definition	Units
R_{ss}	heat transfer resistance of stainless steel plate	m^2K/W
R_t	total heat transfer resistance	m^2K/W
U	overall heat transfer coefficient	W/m^2K
U_n	normalised overall heat transfer coefficient	
U_o	initial overall heat transfer coefficient	W/m^2K