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SYNOPSIS

Water saving and energy saving are the theme of realizing social sustainable development. The shortage of water resources is a difficult problem in China. The development of water saving irrigation is an important means to effectively alleviate the contradiction between supply and demand of water resources, vigorously develop agricultural production and ensure food security. Sprinkler irrigation is a kind of effective agricultural water saving irrigation method, the existing research of the sprinkler irrigation technology mainly concentrated in saving water and reducing energy consumption. However, little study has been done on the non-circular jet under low-intermediate pressure as knowledge on jet breakup morphologies in the air is still limited. Therefore, the hydraulic performance and jet breakup characteristics of the sprinkler with non-circular nozzles are studied from the view of macrocosm and microcosm. The movement and dispersion mechanisms of the jets are understood, and the problem of uneven water distribution of the sprinkler under low pressure conditions is solved. The expected results would be useful in academia and of practical significance to the design and optimization of low-pressure sprinklers.

This book can be used as a reference for engineers and technicians engaged in the research of the sprinkler irrigation and micro-irrigation technologies and the water-saving irrigation project, as well as the teachers and students who major in agricultural engineering fields in colleges and universities.

PREFACE

With the sustainable development of society, people depend on the water more and more, resulting in a constant shortage of water resources. The phenomena of large agricultural water consumption, low efficiency of water used, and serious water waste are especially common in China. Therefore, the development of water-saving irrigation technology is considered as one of the important ways to effectively alleviate the increasingly acute contradiction between supply and demand of the water resources in China, which is also an important means to guarantee the food security, the effective supply of important agricultural products, and the sustainable development of agriculture. Many scientists focused their research on saving water and reducing energy input of sprinkler irrigation system but maintained an acceptable sprinkler irrigation quality.

Dr. Yue Jiang has conducted extensive researches on sprinkler hydraulic performance and jet breakup characteristics for many years. In particular, the jet breakup characteristics of the sprinkler with circular and non-circular nozzles were studied under the low – intermediate working pressures. Obviously, these results are good contributions to the optimal design of the sprinkler, leading to the improvement of the hydraulic performance of the sprinkler under low working pressures. In recent years, Dr. Jiang has published many articles related to the jet breakup characteristics of the sprinkler with different nozzle types in international and national authoritative journals, such as *Biosystems Engineering*, *Journal of irrigation and drainage engineering*, *Irrigation and Drainage*, et al. These articles have caused the interests of many peer experts around the world.

The publication of this book will be able to demonstrate the current achievements related to irrigation science in China and abroad. Furthermore, the book is beneficial to understand the jet breakup mechanism of the sprinkler under the low-intermediate working pressures. With the shortage of water resources all over the world, there is no shirking of the responsibility for the agricultural researchers to study the new water and energy saving technologies. I am very pleased to see that young scientists have also obtained extensive achievements in the field of theoretical and experimental study of new irrigation technologies. It is my great pleasure to write the preface and to congratulate the publication of this book.

Hong Li

Professor

Dean of the Graduate School

Jiangsu University

May，2020

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A part of the experiments concerning sprinkler irrigation hydraulic performances and jet characteristics were conducted when I was a doctoral candidate at the Research Center of Fluid Machinery Engineering and Technology, Jiangsu University, China. I was assisted by Dr. Chao Chen, assistant research fellow, Mrs. Xiaoyin Zhou and Mrs. Lin Hua, postgraduate students, Research Center of Fluid Machinery Engineering and Technology, Jiangsu University, for the indoor experiments conducted in China. The Research Center of Fluid Machinery Engineering and Technology of Jiangsu University provided the experimental sites and sprinkler irrigation installations for the indoor experiments conducted in this study. All of the people who contributed to the experiments are gratefully acknowledged.

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May, 2020

NOMENCLATURE

1. Symbols

$\boldsymbol{\tau}$	Viscous stress tensor
τ_{ij}	Trace-Free tensor component of the sub-grid stress
σ	Surface tension coefficient, N/m
α	Angle between the jet boundary line and the jet axis, °
α_0	Elevation angle of the sprinkler, °
ρ_g	Gas density, kg/m^3
ρ_l	Water density, kg/m^3
ρ_i	Point water application rate, mm/h
$\overline{\rho}$	Average water application rate, mm/h
μ	Water viscosity, kg/(m・s)
η_0	Initial amplitude of the surface wave, mm
Δ	Representative grid spacing, mm
Δt	Time step, s
Δx_1, Δx_2, Δx_3	Grid dimensions in the three coordinate directions
θ	Cone angle of nozzle, °
ϕ	Level set function
$\mu(\phi)$	Viscosity, kg/(m・s)
$\rho(\phi)$	Density, kg/m^3
$\kappa(\phi)$	Curvature
$H(\phi)$	Heaviside function
a	Radius of the jet, mm
A	Discharge area of the nozzle, mm^2
A_a	Projected area, mm^3
A_2	Discharge area of the non-circular nozzle, mm^2
A^+	Semi-empirical constant
$b_{1/2}$	Half width of the jet
C_s	Smagorinsky constant
C_{s0}	Van Driest constant
d_a	Single projected area diameter, mm
d_1	Outlet diameter of the jet, mm
D_h	Equivalent diameter of non-circular orifice, mm
g	Gravitational acceleration, m/s^2
h	Mesh size, mm
h_w	Water depth, mm
h_0	Outlet width of the jet, mm
h_1	Physical length between two wave crests on both sides of the jet surface, mm
H_0	Nozzle pressure, m
H	Working pressure head of the sprinkler, m
I_m	m-Bessel function of the first kind
k	Complex wave number
K_m	m-Bessel function of the second kind
L	Wetted perimeter of the non-circular orifice, mm
L_b	Jet breakup length, mm
L_c	Jet initial length, mm
L'_b	Relative error between the jet breakup lengths of the RANS simulation and experiment
L''_b	Relative error between the jet breakup lengths of the LES method and experiment
n	Number of points and collectors
p	Working pressure, kPa
p_d	Atomization index
p_σ	Additional pressure due to surface tension
P_∞	Static pressure, Pa
Q	Flow rate of the sprinkler, m^3/h

R	Sprinkler wetted radius, m
R_{PY1}	Wetted radius of the PY_1 impact sprinkler, m
R_{PYS}	Wetted radius of the PYS plastic impact sprinkler, m
R_{PS}	Wetted radius of the PSH and PSBZ progressive fluidic sprinkler, m
Re	Reynolds number
s	Complex growth rate
$\boldsymbol{S}$	Strain rate tensor
S_i	Area of the point, m^2
$s_{\max}$	Maximum perturbation growth rate
T_∞	Static temperature, K
$\boldsymbol{u}$	Velocity vector, m/s
u	Velocity at different sections of the free jet from the axis y, m/s
u_0	Jet outlet velocity, m/s
u_m	Velocity along the axis of the jet, m/s
U_∞	Velocity of the quiescent air, m/s
V_t	Instantaneous inlet velocity of the jet, m/s
V_{ave}	Average velocity, m/s
V_{rand}	Velocity disturbance, m/s
We	Weber number
X_i	Water depth collected by collector No. i, mm
$\overline{X}_i$	Average water depth collected in every collector, mm
x -	x-axis
y -	y-axis
z -	z-axis

2. Abbreviations

CLSVOF	Coupled level set-volume of fluid
DPIV	Digital PIV
EDM	Electric discharge machining
HRIC	High resolution interface capturing
HSP	High-Speed photography
LED	Light-Emitting diode
LES	Large eddy simulation
LIF	Laser-Induced fluorescence
PDA	Phase doppler anemometry
PISO	Pressure-Implicit with splitting of operators
PIV	Particle image velocimetry
PRESTO	Pressure staggering option
RANS	Reynolds-Averaged Navier-Stokes
RSM	Reynolds stress model
UDF	User-Defined function
UCC	Christiansen's uniformity coefficient, %
VOF	Volume of fluid
SIMPLE	Semi-implicit method for pressure linked equations

CONTENTS