燃氣導管之熱膨脹移位對導向葉片三維流區域之影響

賴佑民、吳佩學

E-mail: 9015626@mail.dyu.edu.tw

摘 要

造成燃氣輪機一級導向葉片（靜葉片）前端與外環基座同時龜裂之原因，目前工業界還沒有徹底掌握。雖然葉片內部冷卻及膜冷卻之設計可能尚有缺失，然而造成此一缺失之原因有可能是低估了葉片外部熱傳。本研究主要探討一項在估算一級導向葉片外部熱傳時經常被忽略的一項因素，亦即燃氣導管出口處之熱膨脹移位對一級導向葉片表面熱傳係數分佈變化的影響。 由於一級導向葉片之破壞經常被發現是發生在前端、尾端與靠近根部處，以及端壁基座環上，因此要探討這些地方的外部熱傳，對於該區流場的認識非常必要。諸多研究成果已指出，靠近葉片端壁處之流場為極複雜的三維流，含有蹄形渦漩，通道渦漩，及角落渦漩等二次流的交互作用，而這些渦漩之形成方式，與上游之邊界層之發展情形亦有密切的關係。因為燃氣導管出口與一級靜葉片環形基座之對合情形明顯地會影響葉片端壁處三維流場之發展，所以忽略燃氣導管之熱膨脹移位，對靜葉片近端壁處外部熱傳之估算，似乎在考慮上有欠周詳。 本研究以實驗方式探討氣輪機燃氣導管出口處之熱膨脹移位對一級導向葉片基部流場的改變與熱傳係數分佈變化的影響。實驗之靜葉片模型採兩個半葉片為之，而半葉片模型之設計乃藉CFD模擬來決定半葉片兩側之間隙以近似葉片陣列之情形。燃氣導管之熱膨脹移位相對於靜葉片環形基座之非對合情形以一階梯代表之。熱傳係數之量測則採用暫態熱傳液晶熱像法。 實驗結果顯示，當燃氣導管之出口與葉片環形基座之對合發生易位時，一級導向葉片端壁及吸力面基部之熱傳係數提昇，壓力面之熱傳係數則有稍微下降之趨勢。吸力面受三維流影響之三角型區域明顯變大，顯示三維流之結構受到改變，靜葉片破壞之機率相對提昇。

關鍵詞 : 導向葉片，燃氣導管，端壁，熱傳係數，暫態熱傳，液晶熱像法。

目錄

參考文獻

【1】KAWAIKE, K., ANZAI, S., TAKEHARA, I., SASADA, T., AND MATSUZAKI, H., 1993, "ADVANCED COOLING DESIGN OF TURBINE BLADES WITH SERPENTINE COOLING PASSAGES," 20TH INTERNATION AL CONGRESS ON COMBUSTION ENGINES, PAPER G12. 【2】CHUNG, J.T. AND SIMON, T.W., 1990, "THREE - DIMENSIONAL FLOW NEAR THE BLADE/ENDWALL JUNCTION OF A GAS TURBINE: VISUALIZATION IN A LARGE - SCALE CASCADE SIMULATOR," ASME PAPER 90-WA/HT-4. 【3】SPENCER, M.C., JONES, T.V., AND LOCK, G.D., 1996, "ENDWALL HEAT TRANSFER MEASUREMENT -S IN AN ANNULAR CASCADE OF NOZZLE GUIDE VANES AT ENGINE REPRESENTATIVE REYNOLDS AND MACH NUMBERS," INT. J. HEAT AND FLUID FLOW, VOL. 17, NO. 2, PP.139-147. 【4】GOLDSTEIN, R.J., AND SPORES, R.A., 1988, "TURBULENT TRANSPORT ON THE ENDWALL IN THE REGION BETWEEN ADJACENT TURBINE BLADES," ASME JOURNAL OF HEAT TRANSFER, VOL. 110, PP. 862-869. 【5】TAKEISHI, K., MATSUURA, M., AOKI. S., AND SATO, T., 1989, "AN EXPERIMENTAL STUDY OF HEAT TRANSFER AND FILM COOLING ON LOW ASPECT RATIO TURBINE NOZZLE," ASME JOURNAL OF TURBOMACHINERY, VOL. 112, PP. 504-511. 【6】YAMAMOTO, A., 1987, "PRODUCTION AND DEVELOPMENT OF SECONDARY FLOWS AND LOSSES IN TWO TYPES OF STRAIGHT TURBINE CASCADE: PART 1 - A STATOR CASE," ASME JOURNAL OF TURBOMAC -HINERY, VOL. 109, PP. 186-193. 【7】CHUNG, J.T., SIMON, T.W., AND BUDDHAVARAPU, 1991, "THREE - DIMENSIONAL FLOW NEAR THE BLADE/ENDWALL JUNCTION OF A GAS TURBINE: APPLICATION OF A BOUNDARY LAYER FENCE," ASM -E PAPER 91-GT-45. 【8】GOLDSTEIN, R.J., AND CHEN, P.H., 1987, "FILM COOLING OF A TURBINE BLADE WITH INJECTI -ON THROUGH TWO ROWS OF HOLES IN THE NEAR-ENDWALL REGION," ASME JOURNAL OF TURBOMACH -INERY, VOL. 109, PP. 588-593. 【9】LANGSTON, L.S., NICE, M.L., AND HOOPER, M.R., 1977, "THREE-DIMENSIONAL FLOW WITHIN A TURBINE CASCADE PASSAGE," ASME JOURNAL OF ENGINEERING FOR POWER,

VOL. 99, PP. 21- 28. 【10】SIEVERDING, C.H., 1985, "RECENT PROGRESS IN THE UNDERSTANDING OF BASIC ASPECTS OF SE -CONDARY FLOWS IN TURBINE BLADE PASSAGES," ASME JOURNAL OF ENGINEERING FOR GAS TURBI -NES AND POWER, VOL. 107, PP. 248-257. 【11】LANGSTON, L.S., 1980, "CROSSFLOWS IN A TURBINE CASCADE PASSAGE," ASME JOURNAL OF ENG -INEERING FOR POWER, VOL. 102, PP. 866-874. 【12】GRAZIANI, R.A., BLAIR, M.F., TAYLOR, J.R., AND MAYLE, R.E., 1980, "AN EXPERIMENTAL S -TUDY OF ENDWALL AND AIRFOIL SURFACE HEAT TRANSFER IN A LARGE SCALE TURBINE BLADE CA -SCADE," ASME JOURNAL OF ENGINEERING FOR POWER, VOL. 102, PP. 257-267 【13】GOLDSTEIN, R.J., AND CHEN, P.H., 1985, "FILM COOLING ON A GAS TURBINE BLADE NEAR THE END WALL," ASME JOURNAL OF ENGINEERING FOR GAS TURBINES AND POWER, VOL. 107, PP. 117 -122. 【14】SHARMA, O.P., AND BUTLER, T.L., 1987, "PREDICTIONS OF ENDWALL LOSSES AND SECONDARY F -LOWS IN AXIAL FLOW TURBINE CASCADE," ASME JOURNAL OF TURBOMACHINERY, VOL. 109, PP. 229-236. 【15】SONODA, T., 1985, "EXPERIMENTAL INVESTIGATION ON SPATIAL DEVELOPMENT OF STREAMWISE VORTICES IN A TURBINE INLET GUIDE VANE CASCADE," ASME PAPER NO. 85-GT-20 【16】CHUNG, J.T., 1992, "FLOW AND HEAT TRANSFER EXPERIMENTS IN THE TURBINE AIRFOIL/ENDWAL -L REGION," PH.D. THESIS, DEPARTMENT OF MECHANICAL ENGINEERING, UNIVERSITY OF MINNESO -TA, MINNEAPOLIS, MN. 【17】WANG, P.H., OLSON, S.J., GOLDSTEIN., R.J., AND ECKERT E.R.G., 1997, "FLOW VISUALIZAT -ION IN A LINEAR TURBINE CASCADE OF HIGH PERFORMANCE TURBINE BLADES," JOURNAL OF TUR -BOMACHINERY, VOL. 119, PP. 1-8. 【18】BLAIR, M.F., 1974, "AN EXPERIMENTAL STUDY OF HEAT TRANSFER AND FILM COOLING ON LARGE - SCALE TURBINE ENDWALLS," ASME JOURNAL OF HEAT TRANSFER, VOL. 96, PP. 524-529. 【19】CHEN, P.H., 1984, "FILM COOLING OF A TURBINE BLADE BY INJECTION THROUGH TWO ROWS OF STAGGERED HOLDS IN NEAR-END-WALL REGION," M.S.M.E THESIS, DEPARTMENT OF MECHANICAL ENGINEERING, UNIVERSITY OF MINNESOTA, MINNEAPOLIS, MN. 【20】CHEN, P.H., 1988, "MEASUREMENT OF LOCAL MASS TRANSFER FROM A GAS TURBINE BLADE," PH. D THESIS, DEPARTMENT OF MECHANICAL ENGINEERING, UNIVERSITY OF MINNESOTA, MINNEAPOLI -S, MN. 【21】CHEN, P.H., 1991, "CONVECTIVE TRANSPORT PHENOMENA ON THE SUCTION SURFACE OF A TURBIN -E BLADE INCLUDING THE INFLUENCE OF SECONDARY FLOW NEAR THE ENDWALL," ASME PAPER 91- GT-35. 【22】MOFFAT, R.J., 1990, "EXPERIMENTAL HEAT TRANSFER," KEYNOTE PAPER, KN11, PROC. 9TH INT. HEAT TRANSFER CONF., JERUSALEM, VOL. 1.,PP. 882-890. 【23】CLIFFORD, R.J., JONES T.V., AND DUNNE, S.T., 1983, "TECHNIQUES FOR OBTAINING DETAILE D HEAT TRANSFER COEFFICIENT MEASUREMENT WITHIN GAS TURBINE BLADE AND VANE COOLING PASSAGES," ASME PAPER 83-GT-58. 【24】HIPPENSTEELE, S.A., RUSSEL, L.M., AND TORRES, F.J., 1985, "LOCAL HEAT-TRANSFER MEASU -REMENTS ON A COMPOSITE OF A HEATER ELEMENT AND LIQUID CRYSTALS.," JOURNAL OF ENGINE -ERING FOR GAS TURBINES AND POWER, VOL. 107,PP953-960. 【25】MARTINEZ-BOTAS, R.F., LOCK, G.D., AND JONES, T.V.,1994, "HEAT TRANSFER MEASUREMENTS IN AN ANNULAR CASCADE OF TRANSONIC GAS TURBINE BLADES USING THE TRANSIENT LIQUID CRY -STAL TECHNIQUE," ASME PAPER 94-GT-172. 【26】VON WOLFERSDORF, J., HOECKER, R., SATTELMAYER, T., 1993,"A HYBRID TRANSIENT STEP-HEA -TING TRANSFER MEASUREMENT TECHNIQUE USING HEATER FOILS AND LIQUID-CRYSTAL THERMOPGR -APHY," JOURNAL OF HEAT TRANSFER, VOL. 115, PP. 319-324. 【27】HERZIG, H.Z., HANSEN. A.G., AND COSTELLO, G.R., 1953, "VISUALIZATION STUDY OF SECON -DARY FLOW IN CASCADES," NACA TN 1163. 【28】GREGORY-SMITH, D.G., GRAVES, C.P., WALSH, J.A., AND FULTON, K.P., 1988, "TURBULENCE MEASUREMENTS AND SECONDARY FLOWS IN A TURBINE ROTOR CASCADE," ASME PAPER 88-GT-244. 【29】SATO, T., AOKI, S., TAKEISHI, K. AND MATSUURA, M., 1987, "EFFECT OF THREE - DIMENSIO -NAL FLOW FIELD ON HEAT TRANSFER PROBLEMS OF A LOW ASPECT RATIO TURBINE NOZZLE," PRE -SENTED AT 1987 TOKYO INTERNATIONAL GAS TURBINE CONGRESS, 87-TOKYO-IGTC-59. 【30】BAILEY, D.A., 1980, "STUDY OF MEAN- AND TURBULENT-VELOCITY FIELDS IN A LARGE - SCALE TURBINE-VANE PASSAGE," ASME JOURNAL OF ENGINEERING FOR POWER, VOL. 102, PP. 88-97. 【31】PRUMPER, H. ,1972, "APPLICATION OF BOUNDARY LAYER FENCES IN TURBOMACHINERY," AGARD OGRAPH, NO. 164, PP.311-331. 【32】KINNEAR, I.S., MAY, A.L., AND WALL, R.A., 1980, "SECONDARY CONTROL IN AXIAL FLUID MA -CHINE, " UK PATENT APPLICATION GB 2 042 675 A 【33】KRISHNAMOORTHY, V., PAI, B.R., AND SUKHATME, S.P., 1988, "INFLUENCE OF UPSTREAM FLOW CONDITIONS ON THE HEAT TRANSFER TO NOZZLE GUIDE VANES," JOURNAL OF TURBOMACHINERY, VOL. 110, PP. 412-416. 【34】HIROTA, M., FUJITA, H., AND YOKOSAWA, H., 1994, "EXPERIMENTAL STUDY ON CONVECTIVE HE -AT TRANSFER FOR TURBULENT FLOW IN A SQUARE DUCT WITH A RIBBED ROUGH WALL (CHARACTER -ISTICS OF MEAN TEMPERATURE FIELD)," ASME, JOURNAL OF HEAT TRANSFER, VOL. 116, PP. 332-340. 【35】IRELAND, P.T., WANG, Z., AND JONES, T.V., 1995, "MEASUREMENT TECHNIQUES: LIQUID CRYS -TAL HEAT TRANSFER MEASUREMENTS," VON KARMAN INSTITUTE FOR FLUID DYNAMICS LECTURE SE -RIES 1995-01, PP. 1-67. 【36】吳佩學，1999，"應用液晶技術之熱傳實驗系統的建立"完成報告，計劃編號NSC87-TPC-E-212-001。 【37】BAUGHN, J.W., BUTLER, R.J., BYERLEY, A.R., AND RIVIR, R.B., 1995, "AN EXPERIMENTAL I -NVESTIGATION OF HEAT TRANSFER, TRANSITION AND SEPARATION ON TURBINE BLADES AT LOW REYNOLDS NUMBER AND HIGH TURBULENCE INTENSITY," ASME, 95-WA/HT-25, PP.1-13