

Figure 1: SEM photography of the cross section of a riblet structured surface (Fraunhofer IFAM, source: Internet)



length	63,7 m
wing span	60,3 m
height	16,9 m
max. speed	875 km/h
max. flight level	12.500 m
max. take of weight	271.000 kg
max. range	12.700 km
seats	221

Figure 2: Characteristics of Airbus A340-300 aircraft

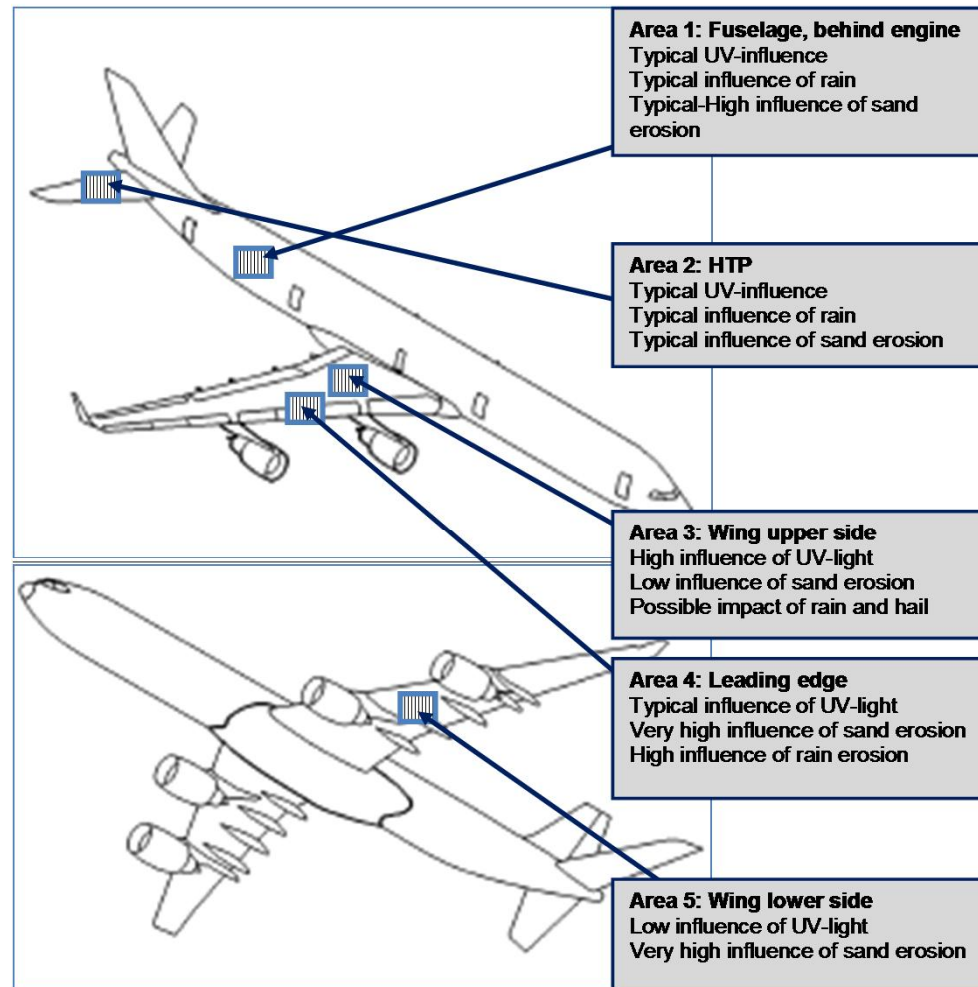


Figure 3: Riblet Application Areas on an Airbus A340-300 aircraft

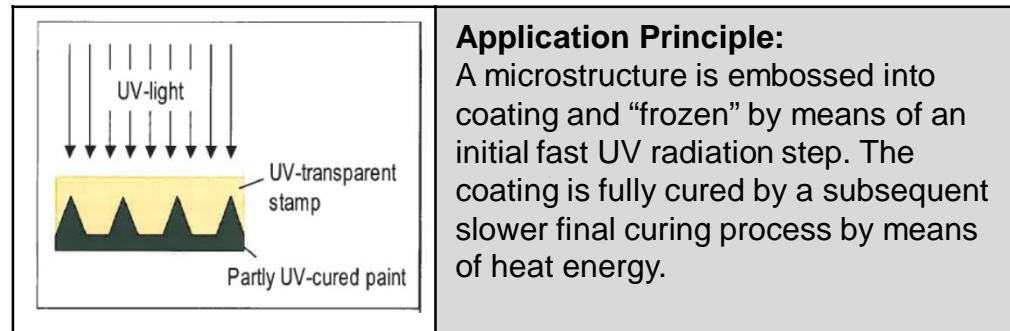


Figure 4: General application procedure for micro-structured coatings (source: Airbus).

Engineering Order Type	EO Number	Content	Date
Modification	331819	The modification covered with this EO consists of temporarily applying several riblet patches and an anti-erosion coating on the LH fuselage skin of two aircrafts A340-300, D-AIGI and D-AIGH for the propose to investigate the degradation and soiling behaviour under flight conditions.	June 1 st , 2011 <i>(rev. July 31st, 2013; extension of test phase)</i>
Multiple Inspection	331818	This EO orders to inspect the micro-structured coating and the anti-erosion coating applied acc. to EO 331819 to verify the samples conditions.	June 28 th 2011

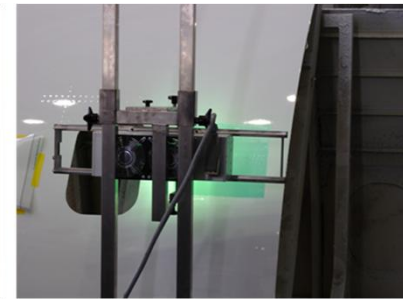
Table 1: Lufthansa Technik Engineering Orders for Application / Removal and Inspection Process of sample patches.



a. Preparation of test wall

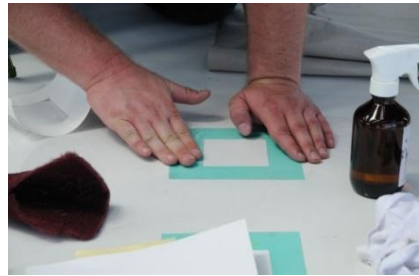


b. Application of stencil and paint



c. UV hardening process on test wall

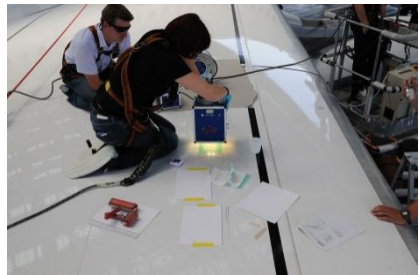
Figure 5: Trial of patch application process at a test wall at Lufthansa Technik (2011).



a. *Cleaning, application of stencil on pre-defined spot*



b. *Application of paint material*



c. *Embossing of riblet structure and UV hardening*



d. *Removing of stencil; riblet test patch is ready*

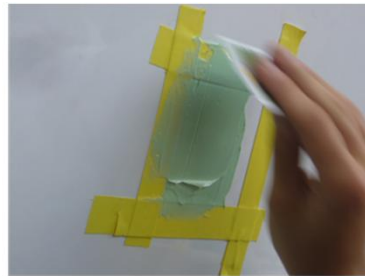
Figure 6: Application of first set of test patches on aircraft D-AIGH (LHT, June 29th 2011)

Area	Patch	Type	Material	
			Provider	Type
Wing Upper Area	Wing Patch #1	Riblet	A	Ma1
	Wing Patch #2	Riblet	B	Mb1
	Wing Patch #3	Riblet	A	Ma2
	Wing Patch #4	Riblet	C	Mc1
Horizontal Stabiliser	Upper HTP #1	Riblet	A	Ma1
	Upper HTP #2	Riblet	B	Mb1
	Upper HTP #4	Riblet	C	Mc1
	Lower HTP #1	Riblet	A	Ma1
Fuselage	Fuselage Top #3	Riblet	A	Ma2
	Fuselage Bottom #3	Riblet	A	Ma2
Wing	Wing Patch #5	Smooth Coat	C	Clearcoat
Horizontal Stabiliser	Upper HTP #5	Smooth Coat	C	Clearcoat

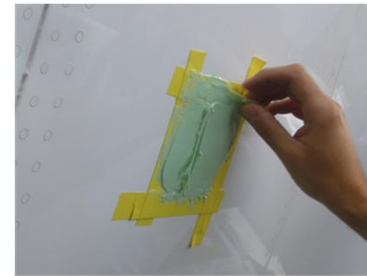
Table 2: Patch Locations and Material used.



a. Marking the patches



b. Application of silicone paste



c. Peeling off paste after curing

Figure 7: Principles of De-Moulding Process of the Fuselage Patches

Reporting Sheet

Tail sign: _____ Name: _____	Flight hours/Flight cycles: _____ Date: _____
---------------------------------	--

Wing Patch Nr. 5

Wing Patch Nr. 1

Wing Patch Nr. 2

Wing Patch Nr. 3

Wing Patch Nr. 4

Wing patch Nr. 5:

Gloss: Spot 1: _____
Spot 2: _____
Spot 3: _____

Roughness: Spot 1: _____
Spot 2: _____
Spot 3: _____

Visual inspection:
Findings: _____

Wing patch Nr. 3:

Visual inspection:
Findings: _____

Wing patch Nr. 4:

Visual inspection:
Findings: _____

Wing patch Nr. 1:

Visual inspection:
Findings: _____

Wing patch Nr. 2:

Visual inspection:
Findings: _____

1 of 3

Figure 8: Reporting Sheet for Gloss / Roughness Measurements and Visual Inspection.

PROJECT PERIOD - LH-LHT-RFT																												
START: 28.06.2011																												
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

		2011						2012						2013																
		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
D-AIGH A343	Inspection Step	A		1		2	3	4		5		6		7	8		9						10	11	12	R				
	Date	29.06.		16.08.		29.10.	10.11.	30.12.		24.02.		21.04.		08.06.	26.07.		06.09.						06.03.	04.04.	15.05.	27.06.				
	Patch Flight Hours	0		787		1.446	2.108	2.847		3.591		4.324		4.983	5.685		6.320						8.435	8.816	9.441	10.125				
	Patch Flight Cycles	0		86		155	225	307		391		481		558	642		718						995	1.045	1.115	1.195				
D-AIGH A343	Inspection Step		A			1				2	3		4		5	6							7	8				9	10	11
	Date		07.07.			26.10.				06.02.	30.03.		17.05.		05.07.	21.08.							09.03.	30.04.				01.08.	18.09.	31.10.
	Patch Flight Hours		0			1.182				2.552	3.270		4.054		4.826	5.587							8.448	9.240				10.413	11.104	11.801
	Patch Flight Cycles		0			131				287	377		472		562	650							1.042	1.139				1.272	1.350	1.428

A = Application
R = Removal

Table 3: De-Moulding Dates, Flight Hours and Flights Cycles per Test Aircraft.

		PROJECT PERIOD - LH-LHT-RFT																													
		START: 28.06.2011																													
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
		2011												2012												2013					
		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	
D-AIGH A343	Inspection Step	A	1	2	3	4			5		6		7	8		9						10	11	12	R						
	Patch Flight Hours	0	787	1,446	2,108	2,847			3,591		4,324		4,983	5,685		6,320						8,435	8,816	9,441	10,125						
	Patch Flight Cycles	0	86	155	225	307			391		481		568	642		718						995	1,045	1,115	1,195						
Wing	Riblet Patch	Erosion	Ma1	nil		nil		nil	nil	nil		nil		X		nil	X		nil				X	nil	X						
			Mb1	nil		nil		nil	nil	nil		X		X		X	X		X					X	X	X					
			Ma2	nil		nil		nil	nil	nil		nil		nil	nil		nil							nil	nil	X					
			Mc1	nil		nil		nil	nil	nil		nil		nil	nil		nil							nil	nil	nil					
	Erosion Patch	Gloss	60 °	71		69		67	71	71		67		70		52	49		65						55	70					
			85 °	92		93		95	94	94		93		90		83	78		89							77	89				
HTP	Riblet Patch	Erosion	Ma1	nil		nil		nil	nil	nil		nil		nil	nil		nil						nil	nil	nil						
			Mb1	nil		nil		nil	nil	nil		nil		nil	nil		nil							nil	nil	nil					
			Mc1	nil		nil		nil	nil	nil		nil		nil	nil		nil							nil	nil	X					
			Ma1	nil		nil		nil	nil	nil		nil		nil	nil		nil							nil	nil	nil					
	Erosion Patch	Gloss	60 °	72		71		74	67	67		78		81		65	56		64						52	48					
			85 °	87		87		92	93	93		93		91		90	82		88							76	83				
Fuselage	Riblet Patch	Erosion	Ma2	nil		nil		nil	nil	nil		nil		nil	nil		nil						nil	nil	nil						
			Ma2	nil		nil		nil	nil	nil		nil		nil	nil		nil							nil	nil	nil					

Table 4: Results of visual inspections and gloss measurements of the patches on aircraft D-AIGH, prior to de-moulding.

		PROJECT PERIOD - LH-LHT-RFT																																			
		START: 28.06.2011																																			
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28							
		2011												2012												2013											
		JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT							
D-AIGI A343	Inspection Step		A			1																															
	Patch Flight Hours		0			1,182					2,552	3,270	4,054		4,826	5,587							8,448	9,240				10,413	11,104	11,801							
	Patch Flight Cycles		0			131					287	377	472		562	650							1,042	1,139				1,272	1,350	1,428							
Wing	Riblet Patch	Erosion	Ma1			nil				nil			nil		nil							nil	nil			nil		nil									
			Mb1			X					X			X			X							X	X			X		nil							
			Ma2			nil					nil			nil			X							nil	nil			nil		nil							
			Mc1			X					X			nil			X							nil	nil			nil		nil							
	Erosion Patch	Gloss	60 °			66					78		70			80							34	70													
			85 °			92					97		94			92								24	92												
HTP	Riblet Patch	Erosion	Ma1			nil				nil			nil		nil							nil	nil			nil		nil									
			Mb1			nil					nil			nil			nil							nil	nil			nil		nil							
			Mc1			nil					nil			nil			nil							nil	nil			nil		nil							
	Erosion Patch	Gloss	Ma1			nil				nil			nil			nil							nil	nil			nil		nil								
			60 °			67						72		73			88							82	72												
			92						93		90			90								30	88														
Fuselage	Riblet Patch	Erosion	Ma2			nil				nil			nil		nil							nil	nil			nil		nil									
			Ma2			nil					nil			nil			nil							nil	nil			nil		nil							

Table 5: Results of visual inspections and gloss measurements of the patches on aircraft D-AIGI, prior to de-moulding.

Area	Patch	Type	Material		Inspections on aircraft	D-AIGH	D-AIGI
			Provider	Type			
Wing Upper Area	Wing Patch #1	Riblet	A	Ma1	Erosion	yes	no
	Wing Patch #2	Riblet	B	Mb1		yes	yes
	Wing Patch #3	Riblet	A	Ma2		some	some
	Wing Patch #4	Riblet	C	Mc1		no	some
Horizontal Stabiliser	Upper HTP #1	Riblet	A	Ma1		no	no
	Upper HTP #2	Riblet	B	Mb1		no	no
	Upper HTP #4	Riblet	C	Mc1		some	no
	Lower HTP #1	Riblet	A	Ma1		no	no
Fuselage	Fuselage Top #3	Riblet	A	Ma2		no	no
	Fuselage Bottom #3	Riblet	A	Ma2		no	no
Wing	Wing Patch #5	Smooth Coat	C	Clearcoat	Gloss degradation	yes	yes
Horizontal Stabiliser	Upper HTP #5	Smooth Coat	C	Clearcoat		yes	no

Table 6: Summary and comparison of the visual inspections on both test aircraft.

Airport	Flights ex FRA	
	D-AIGH	D-AIGI
ADD Addis Abeba	17	7
KRT Khartoum	10	23
Africa	27	30
ATL Atlanta	82	60
BOS Boston	54	66
PHL Philadelphia	61	54
YVR Vancouver	48	52
YYC Calgary		11
YYZ Toronto	56	60
North America	301	303
TLV Tel Aviv	14	18
Middle East	14	18
MAA Madras	73	70
India	73	70
CAN Guangzhou	18	12
NGO Nagoya	84	96
NKG Nanjing	68	61
SHE Shenyang	45	41
Far East	215	210
Global	630	631

Table 7: Flight Routes of the test aircraft D-AIGH and D-AIGI during the test period.