

A method that lends wings

Mathematician **Irmgard Flügge-Lotz** was one of the first female researchers in the field of aerodynamics and automatic control. While working at the **Kaiser Wilhelm Institute for Flow Research**, she succeeded in simplifying the calculations required for aircraft construction. Flügge-Lotz was later appointed the first female Professor of Engineering at Stanford University. In the U.S., her work is still held in high esteem. In Germany, however, she has been all but forgotten.

TEXT **KATJA ENGEL**

Goettingen, 1931. Leading flow researcher Ludwig Prandtl was astonished. His colleague, at 28 just half his age, had just handed him the solution to a mathematical puzzle that nobody had been able to crack for more than ten years. This conundrum was on his "menu", as he called his list of uncompleted research tasks. The result went down in the history of aerodynamic research together with the young researcher's name. The "Lotz method" makes it possible to calculate the lift on an airplane wing with comparative ease.

Prandtl soon made the woman who had so impressed him an (unofficial) Head of Department at the Aerodynamische Versuchsanstalt (AVA, now the German Aerospace Center), part of the Kaiser Wilhelm Institute for Flow Research in Goettingen. This marked the start of Irmgard Lotz's career as an internationally renowned aerodynamics expert and control engineer. Yet before 1960, when she became the first female Professor of Engineering at Stanford University, her scientific career was anything but meteoric.

Irmgard Lotz was born on 16 July 1903 in Hameln. This was the year in which the Wright brothers in the U.S. set a milestone in the development of aeronautics. Working in a wooden shed, the two bicycle mechanics built their "Flyer", one of the first motorized aircraft that was really capable of flying. This was another step forward in the development of the airplane, which at that time was progressing with impressive speed. However, this was still the era of inventors. There was one thing that these bold pioneers of the skies did not manage to do: they were unable to explain the mysterious forces that enable an aircraft to ascend despite being several thousand kilograms heavier than air.

While aeronautic research was also making rapid strides by the end of World War I, these advances were more theoretical in nature. Wing profiles – a major factor in aircraft construction –



A model teacher and researcher: Irmgard Flügge-Lotz was popular with colleagues and students alike.

could only be tested by means of complex wind tunnel measurements. Ludwig Prandtl, who is generally thought to be the founder of aircraft aerodynamics, and his team in Goettingen carried out pioneering work on the theoretical description of lift. However, mathematical calculations of his wing theory turned out to be difficult. In 1919, Albert Betz, a doctoral student in Goettingen who was later to become Prandtl's successor at the Institute, finally succeeded in the describing lift by means of differential equations. However, his formulae were too complex for practical use when constructing new profiles. Expensive wind tunnel testing was still required to show the aerodynamic flow around various wing shapes and determine when turbulence would occur. Moreover, reckoners with slide rules would have to spend days solving the equations – at that time still traditionally a

woman's task. In all, the procedure was unserviceable for purposes of practical aircraft design.

For more than ten years, mathematical descriptions were the biggest obstacle standing in the way of the practical application of wing theory – until Irmgard Lotz developed her method of calculation and astonished Prandtl. "An expert reckoner can calculate the necessary odd and even coefficients [...] in just 2 ½ hours," she wrote in the ZEITSCHRIFT FÜR FLUGTECHNIK UND MOTORLUFTSCHIFFFAHRT, the journal which published her method. It was the long-sought solution that closed the gap between theory and practice. Engineers were now able to calculate the requirements for better-performing wings before the construction work began.

Prandtl's appointment of Irmgard Lotz in 1929 as the only woman in his team of 25 at the AVA paid off. This was not a new situation for her. She was the only woman at the Technical University of Hanover to be awarded a doctorate in applied mathematics. She rejected a job offer from the steel industry. Irmgard

Lotz had known that she wanted to help realize humankind's dreams of flight right from her childhood, when she had watched the huge zeppelins taking off from close by. She later recalled a resolution she had formed before going to university: "I wanted a life that would never be boring. That meant a life in which new things would always occur."

Shortly after her appointment to the Kaiser Wilhelm Institute, the barely 30-year-old mathematician was put in charge of a group of scientists and female mathematicians. Irmgard Lotz became one of the few female Heads of Department at the Kaiser Wilhelm Society, albeit only unofficially. After developing the "Lotz method", she worked on other mathematical solutions for the field of aerodynamics. Then in 1937, Prandtl nominated the talented woman for the post of research professor and submitted the corresponding application to the Reich Ministry of Aviation. His letter listed 13 of her publications. However, the application was rejected. The Nazi regime did not approve of women in leading positions.

In 1938, Irmgard Lotz married civil engineer Wilhelm Flügge and took the name Flügge-Lotz. Disheartened by being rejected for the post of research professor, she followed her husband to Berlin-Adlershof that same year. He accepted a position as

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The author of more than 50 scientific papers, including a 1931 computation on wing lift that contributed to modern aircraft design, Professor Flügge-Lotz had been working in retirement on problems of satellite control, heat transfer and drag of fast-moving vehicles.

Head of Department at the *Deutsche Versuchsanstalt für Luftfahrt* (German Aeronautical Research Laboratory – DVL). She was obliged to stay in the background and obtained a post as a "scientific advisor for aerodynamics and the dynamics of flight". Flügge-Lotz made the most of her time and did the groundwork for one of the first standard textbooks on discontinuous control. One contemporary researcher called it "a groundbreaking contribution to automatic control theory" – a subject that was still in its infancy at the time.

However, Irmgard Flügge-Lotz and Wilhelm Flügge did not stay in what was then the capital city for long. Actions taken by the Nazis led to World War II, and in 1940 the first bombs fell on Berlin. By the time of the heaviest Allied bombing raids in February 1945, the couple, along with part of the DVL, had already moved to Saulgau north of Lake Constance, an area that was less at risk. This meant that after Germany capitulated, they found themselves in French occupied territory. The French enticed many researchers away to Paris. They included Wilhelm Flügge



A breezy testing ground: the flow around wing profiles was tested in the wind tunnel in Goettingen – until the Lotz method made this possible with simple calculations.

and Irmgard Flügge-Lotz, who moved to the *Office national d'études et de recherches aérospatiales*. Here they worked on equal terms as research group leaders.

Although they were both happy in Paris, they lacked opportunities for career advancement. In 1948, they contacted Stanford University in the U.S., where Wilhelm Flügge was subsequently appointed professor. For Irmgard Flügge-Lotz, however, the move was a step backwards, as she merely received the post of lecturer – the lowest rung in the university hierarchy. The rules at Stanford only allowed one half of a married couple to work as a professor at the university.

However, this did not stop Irmgard Flügge-Lotz from carrying out a professor's tasks in the fields of teaching and research. She gave lectures and seminars, supervised doctoral students and moved ahead with her research – in both flow mechanics and automatic control. Students and colleagues alike found it more and more difficult to understand why the "lecturer" was not a "professor". The same question was asked in summer 1960 in an international setting when Flügge-Lotz became the only female delegate from the United States to attend the first congress of the International Federation of Automatic Control in Moscow. Shortly afterwards, Stanford University appointed her to the post of ordinary Professor of Engineering Mechanics, Aeronautics and Astronautics.

The remarkable scientist indefatigably continued her research and teaching activities over the years that followed. Even after she retired in 1968, she remained active in the field of research and received numerous honors. The American Institute of Aeronautics and Astronautics elected her a Fellow – the first woman ever to receive this accolade. The Society of Women Engineers presented her with their Achievement Award, and the University of Maryland awarded her an honorary doctorate. Only in Germany has she been practically forgotten.

On her death in Palo Alto, California, in 1974, a brief obituary was printed in the New York Times. And in 2014, almost 40 years later, Stanford University paid posthumous tribute to her as one of 35 "Engineering Heroes" who had been the driving forces behind the human, social and economic progress made through technology and science.