

Centenary of Yakov Zalmanovich Tsytkin's birth ^{*}

Boris T. Polyak ^{*}

^{*} *Institute for Control Sciences of Russian Academy of Sciences, 65
Profsoyuznaya st., Moscow 117997, Russia (e-mail: boris@ipu.ru)*

Abstract: The paper is devoted to the memory of Yakov Zalmanovich Tsytkin and his “life in feedback control”.

1. INTRODUCTION

Yakov Zalmanovich Tsytkin was an outstanding Russian scientist, academician of the Russian Academy of Sciences, author of more than 300 articles and 12 monographs, laureate of Lenin and prestigious international prizes (IFAC QUAZZA medal, Oldenburger medal, etc). He has made significant contributions to the formation of modern control science, including systems with delay, discrete-time systems, relay systems, adaptive, learning and robust systems.

As Jury [1998] reads: “Since World War II, our field of control has gone through a revolution in the development of many areas of research, important and significant applications, and new innovations in teaching methods. Yakov Tsytkin has been part of this revolution by playing an important role as a pioneer in these developments. The control society worldwide owes much to his talents and many contributions, and his life in feedback control will forever be remembered with affection by those who knew him and with admiration by those who are acquainted with his work.”

In the talk the life and the works of Yakov Zalmanovich Tsytkin will be outlined.

2. EARLY YEARS

Yakov Tsytkin was born on September 19, 1919 in Ekaterinoslav (later - Dnepropetrovsk (USSR), now Dnestr (Ukraine)), where he graduated from high school. Being wireless enthusiast (Fig. 1), he admitted Moscow Institute for Communications and moved to Moscow. The tendency and ability to scientific work, manifested itself in him quite early. He published his first articles at the age of 20, while still a student. Then there was the war, where he served as paratrooper, then severe injury, surgery, hospital, in which Tsytkin continued to study and think about the problems that later formed the basis of his PhD thesis Tsytkin [1945]. The defense was held at the Institute of Automatics and Telemechanics (IAT) in 1945. In the postwar years, the Andronov seminar in IAT played a huge role in the formation of Yakov Zalmanovich as a scientist. Soon (1948) Tsytkin defended (and again in

^{*} The research was supported by Russian Science Foundation, grant 16-11-10015.



Fig. 1. Yakov at his teens

IAT) his doctoral thesis Tsytkin [1948], and his reviewer was academician Andronov. In those years, Yakov Tsytkin was probably the youngest Doctor of Engineering in the country, and a year later he became a Professor. Since 1950, Yakov Zalmanovich officially goes to work in the IAT. From 1956 until his death (more than 40 years), he headed the Laboratory No. 7 of the Institute.

3. WORK ON DELAYED, IMPULSE AND RELAY SYSTEMS

Yakov Zalmanovich's research can be divided into five main areas. The first one is related to *systems with delay*. An article on this topic was published by him in the journal *Avtomatika i Telemekhanika* (Automation and Remote Control) in 1946 (it was the first of 75 publications Tsytkin in this journal — the last, posthumous, appeared in 1999). Yakov Zalmanovich proposed a generalization of the Nyquist criterion for the case of delay. The role of this work was so great that its translation into English in the collection devoted to frequency methods of control theory is placed immediately after Nyquist's seminal article Tsytkin [1946]. It is interesting that some of the ideas of this work happened to be useful much later, in the 90s, in the construction of criteria for robust stability of systems with a delay.

Starting in 1948, Yakov Zalmanovich began to study *pulse systems* (or *intermittent control systems*, later they became known as *discrete-time systems*). These works brought their author world fame. In recent decades,



Fig. 2. Tsypkin and Jury, 1st IFAC Congress, Moscow, 1966

discrete-time systems have played a huge and increasing role in technology, it is enough to recall the digital control and computers. Yakov Zalmanovich developed an adequate mathematical tools for the study of such systems - the method of z-transformation (*discrete Laplace transform*). It was Tsypkin (along with the American scientist E.Jury) who was the founder of the theory of linear discrete-time systems. In 1951 he published the first book on pulse systems Tsypkin [1951], followed by a number of others. Most of them were immediately translated into foreign languages.

The third cycle of Tsypkin's works refers to relay systems; his first publication on this topic appeared in 1952. The systems in which control is of a relay nature, i.e. it can take only two possible values, are considered. Such systems are obviously nonlinear, however, for their analysis Yakov Zalmanovich managed to apply the apparatus of the theory of linear systems with a high gain. Monograph Tsypkin [1955] on relay control included such important results as *Tsypkin criterion* and *Tsypkin locus*. These results received a great response later, after the development of *optimal control* methods, when the relay nature of the control actions turned out to be typical. .

4. ADAPTIVE AND LEARNING SYSTEMS

In 1965 Yakov Zalmanovich completely changed the subject of research. In those years, the words *adaptation*, *learning*, *recognition* became very popular, but the exact meaning of these terms remained unclear. Tsypkin proposed a unified approach to the study of such systems, based on the idea of *recurrent stochastic algorithms* and stochastic approximation techniques, already developed in mathematical statistics. The first plenary report of Yakov Zalmanovich on this topic (1965, 3rd all-Union meeting on automatic control, Odessa) aroused great interest and heated discussion. His monographs Tsypkin [1968], Tsypkin [1970] contributed to the awareness and acceptance of his point of view. Subsequently, the topic of adaptive systems became the main activity of the laboratory headed by him. There appeared such important directions as the

theory of *optimal* and *robust* (i.e. working under conditions of uncertainty of probabilistic characteristics) algorithms of identification and stochastic optimization. More details can be found in Fradkov [2020] and Fradkov & Polyak [2020].

5. ROBUSTNESS

Finally, in 1989, there is another turn in Tsypkin's scientific problems. His attention is drawn to the general problem of control under uncertainty, when the description of the plant itself is not fully known. The problem of robust stability of the characteristic polynomial is typical. Yakov Zalmanovich uses frequency-domain methods and gets the graphical criteria (*the Tsypkin-Polyak plot*). He puts forward a program of *robustization* of the entire linear control theory and achieves new serious results.

His last monograph Tsypkin [1995] is on information theory of identification, it combines the ideas of parametrical and statistical robustness.

6. UNIFIED VIEW ON CONTROL THEORY

In addition to the mentioned main directions, Yakov Zalmanovich was interested in other problems — from the *degree of stability* of linear systems to *neural networks*. At the same time he felt the unity of the whole theory of control. In its center J. Z. Tsypkin put frequency-domain methods for linear systems and the resulting on graphic type criteria like Nyquist and Mikhailov plots. To a lesser extent, he appreciated the apparatus with the description of systems in the state space and optimal control in the spirit of the maximum principle.

Of course, Ya. Z. Tsypkin was first of all a theoretical scientist. But he was well aware of the many practical applications of control science, and his new research was always motivated by the demands of practice. Thus, the emergence of pulse radar systems led Ya. Z. to the need to create the tools for the study of such systems discrete-time control. The practical need for control methods based on the adjustment of the model as information about its functioning is received, served as an incentive for the development of adaptive systems theory. Engineers constantly came to his office to consult concerning the technical problems, and this huge experience was transformed into his generalizing theoretical works.

Tsypkin was distinguished by extraordinary efficiency — he always worked: in the office, at a meeting, at home, on vacation (Fig. 4). He wrote 12 books, more than 300 scientific articles, many brochures, prefaces, book reviews, articles in encyclopedias.

7. AWARDS

The merits of Y. Z. Tsypkin are widely recognized in our country and abroad. He was a full member of the Academy of Sciences of the USSR (later-the Russian Academy of Sciences), winner of the Lenin prize and the Andronov prize, Chairman of the National Committee on Automatic Control, a member of the editorial boards of several journals. Yakov Zalmanovich traveled a lot with



Fig. 3. Tsympkin working at home

reports to international congresses and conferences. Thus, he has been a participant in all IFAC congresses since the first one. Tsympkin was awarded the prestigious Quazza medal (IFAC) with the citation: “*acknowledging his most distinguished contribution to automatic control science and the International Federation of Automatic Control*”; the Hartley medal of the English Institute of Measurement and Control. Rufus Oldenburger medal of the American Society of Mechanical Engineers was awarded “*for his pioneering and fundamental contributions in a wide range of control engineering topics, as a co-founder of the theory of discrete-time control systems, for his development of the discrete and delayed Laplace transforms, and corresponding stability and synthesis methods (Tsympkin Criterion and Tsympkin Locus), for his discovery of the superior performance achievable through deadbeat control, and for his early and seminal contributions to the field of learning and adaptive control*”. A biographical article by C. Bissel, a major specialist in the history of science, is devoted to him Bissel [1992].

8. COLLEAGUES, FRIENDS AND FAMILY

Tsympkin was lucky to have friends all over the world. He contacted such personalities as R.Kalman, R.Bellman, L.Zadeh. His scientific collaboration with E.Jury is worth mentioning — they were writing letters to each other during forty years; now four volumes of the correspondence are stored at IAT.

Yakov Zalmanovich had many students, among them many doctors of sciences and academicians from different Soviet republics. A number of foreign scientists (for example, Lennart Ljung from Sweden and Petar Kokotovich from Yugoslavia) also consider him as their teacher.

Laboratory No. 7 of IPU RAS, which he created and headed for many years, is now named after Ya.Z. Tsympkin. It is still one of the leading theoretical departments in IPU currently.

Yakov Zalmanovich died suddenly, without having had time to hold the next seminar, on December 2, 1997. He was buried at the Troekurov cemetery in Moscow. After the death of Ya. Z. Tsympkin, the largest international control journals issued special issues dedicated to his memory, or published obituaries Jury [1998], Obituary [2001], Obituary [1998].



Fig. 4. Tsympkin’s laboratory, 1978



Fig. 5. Tsympkin, his wife Olga (left) and daughter Inna

In 2007, on the 10th anniversary of the scientist’s death and the 50th anniversary of his laboratory, the book “Yakov Zalmanovich Tsympkin (1919 1997)” was published Polyak [2007], dedicated to the life and work of an outstanding researcher. The memoirs of his friends, relatives, colleagues and students are collected here; some of his speeches and articles are given, and a complete bibliography of his works is given.

Special issues of *Automation and Remote Control* are dedicated to Tsympkin’s centenary ARC [2019]. They include papers of L.Ljung, S.Meerkov, V.Utkin, V.Vapnik, A.Nemirovski, A.Poznyak, A.Tsybakov, A.Nazin, B.Polyak, A.Juditski, P.Scherbakov, M.Khlebnikov and others.

Tsympkin’s wife Olga Aronovna was a permanent support for him during their long (more than 55 years!) happy married life. Fig. 6 presents the lucky family with daughter Inna.

9. PERSONAL REMINISCENCES

My first meeting with Ya. Z. made the strongest impression on me. It was in 1971; authorities wanted to fire me from Moscow State University (for reasons unrelated to science), and I was looking for a new job. Tsympkin knew about my publications on optimization and offered me a position in his laboratory. I explained the possible difficulties; he did not go into details, and our conversation turned into a discussion of the problems that interested him. In fact, my enrollment was not trivial, but Yakov Zalmanovich was perfectly able to solve not only scientific but also bureaucratic problems. Since then and to the

present day I work in Tsypkin's laboratory; we very soon wrote the first joint paper (and there were total 42 of them!), and I learned a lot from him (and not only in science). Now I sit in his former office, at his desk, and on the wall is a portrait of Yakov Zalmanovich.

ACKNOWLEDGEMENTS

This work was supported by Russian Science Foundation, grant 16-11-10015.

REFERENCES

- A.L.Fradkov (2020) A Brief History of Machine Learning: a View from Control Tower. *IFAC-2020*.
- A.L.Fradkov, B.T.Polyak (2020) Adaptive and robust control in the USSR. *IFAC-2020*.
- Ya.Z.Tsypkin(1945) *Foundations of the theory and design of reproducing systems*. PhD dissertation, Moscow, IAT.
- Ya.Z.Tsypkin(1948) *Systems with delayed feedback*. Doctoral dissertation, Moscow, IAT.
- Ya.Z.Tsypkin(1946) Stability of systems with delayed feedback, *Autom. i Telemekh.* No. 2-3; English translation: *Frequency-response methods in control systems*, A.MacFarlane editor, IEEE Press, 1979, PP. 45–56.
- Ya.Z.Tsypkin(1951) *Transient and steady state processes in pulse networks*, Moscow, Gosenergoizdat.
- Ya.Z.Tsypkin(1955) *Relay control systems* Moscow, Gostekhizdat; English translation: Cambridge Univ. Press, 1984.
- Ya.Z.Tsypkin(1958) *Sampling systems theory* Moscow, Fizmatgiz; English translation: Pergamon Press, 1964.
- Ya.Z.Tsypkin(1968) *Adaptation and learning in automated systems* Moscow, Nauka, preliminary version 1965; English translation: NY, Academic Press, 1971.
- Ya.Z.Tsypkin(1970) *Foundations of the theory of learning systems*, Moscow, Nauka, English translation: NY, Academic Press, 1973.
- Ya.Z.Tsypkin(1995) *Information theory of identification*, Moscow, Nauka.
- C. C. Bissel (1992) A Russian life in control: Yakov Tsypkin. *IEE Review*, September, pp. 313-316.
- Obituary (1998). Yakov Zalmanovich Tsypkin (obituary). *Automation and Remote Control*, No. 2.
- E.I.Jury (1998) In memoriam — Yakov Zalmanovich Tsypkin: a life in feedback control *IEEE Trans Autom. Control*, v. 43, No 4.
- Obituary(2001). *Int. Journal of Adaptive Control and Signal Processing*. Special Issue dedicated to the memory of Ya.Z. Tsypkin, V. 15, No 2.
- B.T.Polyak (2007) (editor) *Yakov Zalmanovich Tsypkin (1919-1997)*. Publ. LKI.
- Automation and Remote Control (2019)* Special issues dedicated to Tsypkin's centenary. No 9, 10, 11.