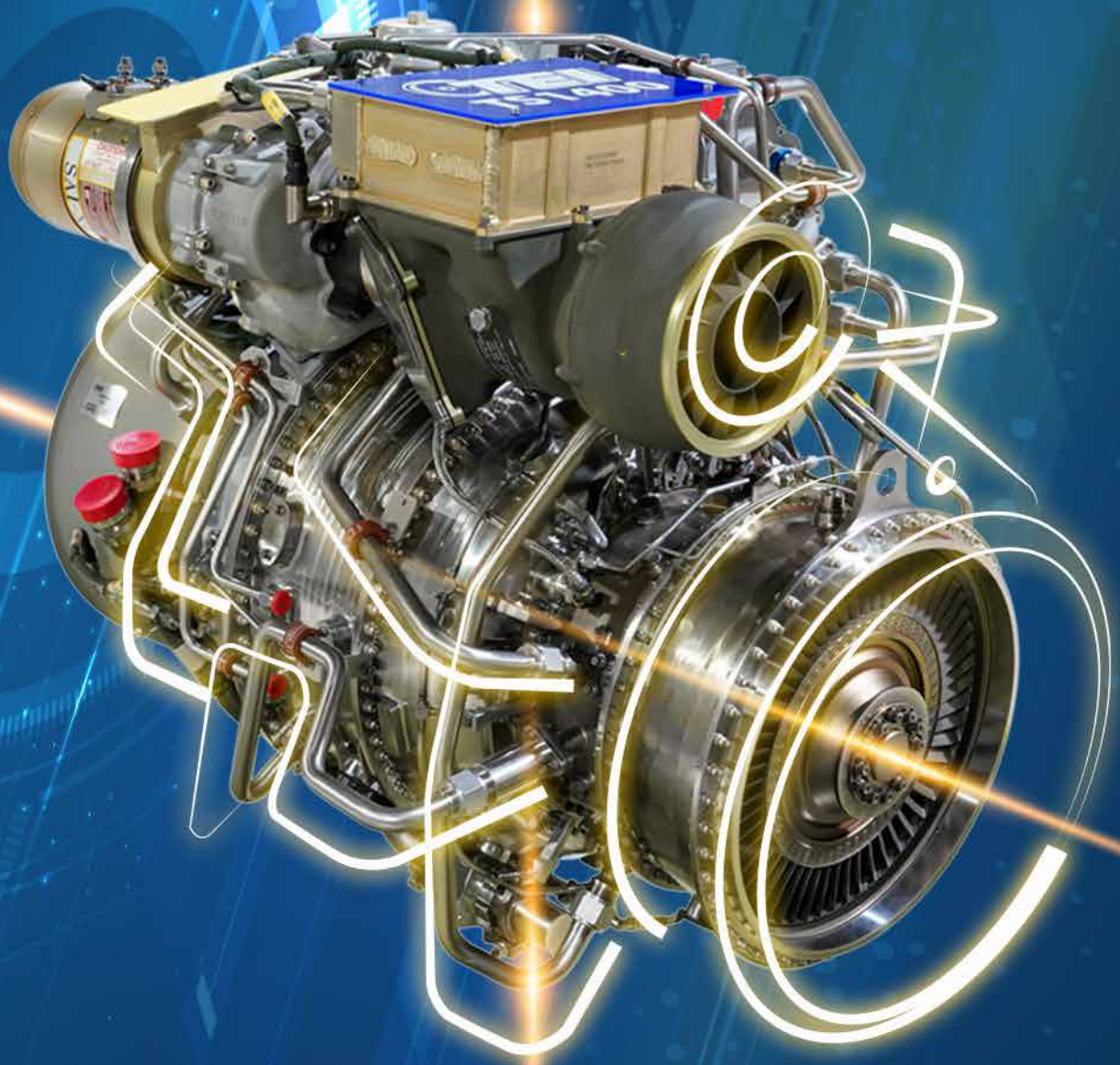
TEI POST
Periodical Publication of TUSAS Engine Industries, Inc.
ISSUE 138 2020

DELIVERY OF THE FIRST NATIONAL HELICOPTER ENGINE TEI-TS1400 AND OPENING CEREMONY OF THE DESIGN CENTER



TEI 35 YEAR

35th YEAR

TEI CONTINUES ITS SUCCESS AND CELEBRATES
35TH ANNIVERSARY IN THE SECOND HALF OF 2020.

FROM THE EDITOR

Dear TEI Post Reader,

As the "Cover Story" in our 138th issue, where we meet with you, our esteemed readers, once again; we handled the delivery of Turkey's first national helicopter engine TEI TS-1400, designed and produced by our company with domestic and national resources, to the Turkish Aerospace Industry and the opening of the Design Center with the participation of our President. We shared with you the latest developments in our company in the "Activities & Projects" and "News from TEI" sections, which also included the "Career and Projects at TEI" event, where we answered questions about our company.

We shared the “Best Employer” award received by our company, "The Company Contributing the Most to Exports from Turkey with the Best Digital Transformation" and "The Turkish Company Contributing the Most to Exports from Turkey with the USA Partnership" awards and other achievements in the “Achievement Board”.

You can read information about the unique seaside town of the Aegean, Foça under section “Travel”.

See you in our 139th issue…

IMPRINT

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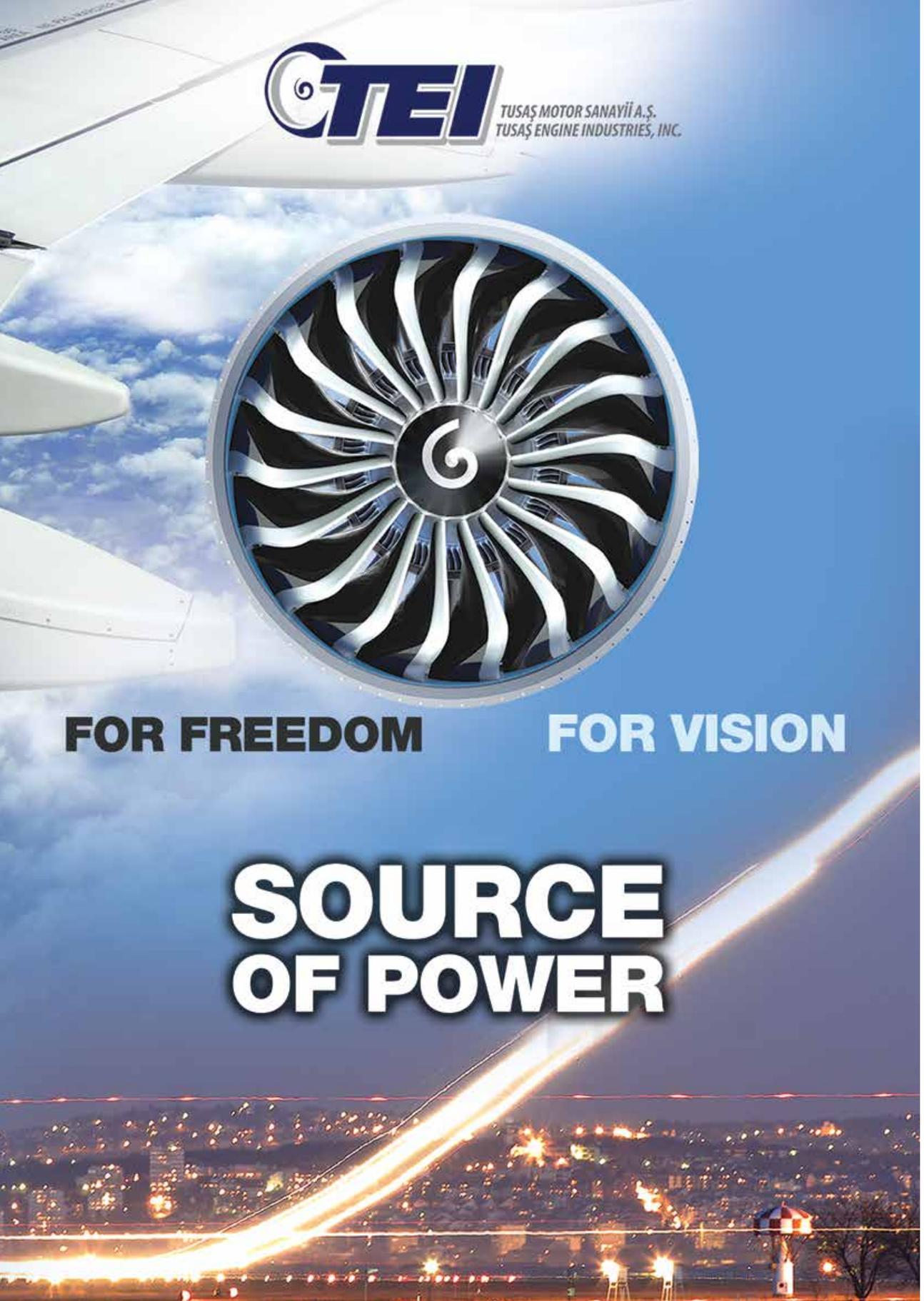


TEI-TS1400, FIRST NATIONAL HELICOPTER ENGINE WAS DELIVERED

I am delighted to meet you once again by virtue of the 138th issue of TEI Post in 2020 the year marking the 35th anniversary of our company's foundation.

For our company, 2020 has still been a year full of great achievements.

In line with the Turboshaft Engine Development Project supported by the Presidency of Defence Industries, we delivered the first prototype of TEI-TS1400 turboshaft engine to Turkish Aerospace to ensure its size and mounting integration with Gokbey Helicopter at a ceremony held on December 5, 2020 with the online participation of our Esteemed President. At the same ceremony, we opened the Design Centre with an office area of 11 thousand square meters and a workshop of 3 thousand square meters.

For TEI-PD170, the first national turbodiesel aviation engine of our company, we completed the whole engine qualification processes. We previously delivered our engine to Turkish Aerospace for ANKA and AKSUNGUR platforms; we also delivered one more engine to BAYKAR for its integration to TB3 platform.

During the second half of 2020, coronavirus pandemic kept influencing the whole world. Where applicable, certain sectors across the world (including education) continued their activities remotely. Showing the importance it attaches to education on every occasion, TEI family donated 1000 devices to the tablet PC campaign, which was initiated to contribute to the education of students with limited access to distance learning and practically turned into mobilization across the country within a short time. We also met up with university students in online environment. The online event "Careers and Projects at TEI" streamed live on our corporate social media accounts, where we told our current projects and answered questions about TEI, attracted intensive attention.

We obtained satisfactory results in two different surveys in 2019 based on the evaluation of our sales figures. We ranked 39th in "Turkey's Top 1000 Exporters" research conducted by the Turkish Exporters Assembly, advancing 4 ranks compared to the previous year, and 2nd in defence and aviation industry. We ranked 94th in "Turkey's Top 500 Industry Enterprises" survey by Istanbul Chamber of Industry, advancing 21 ranks compared to the previous year. In "250 Turkish Companies with the Highest R&D Expenses" survey by Turkishtime Magazine, we became the 9th company that spends the most on R&D.

Towards the end of 2020, we are also blessed to reap the fruits of our works, once again, in the field of human resources. We were awarded the "Employee Loyalty Award" for the third time in a row in the 2019 Best Employers Research organized by Kincentric.

In the program organized by American Companies Association Turkey for awarding companies that contribute to the promotion and strengthening of Turkish-American economic relations, TEI received the awards for "The Turkish Company for Outstanding Contribution to Turkey's Exports with a Partner U.S. Company" and "The Turkish Company for Outstanding Contribution to Turkey's Exports with the Best Digital Transformation".

In line with our mission of becoming a leading engine company on a global scale and the strategies and the vision of the Republic of Turkey, we will continue to remain committed to transform our ongoing and future projects into products. I would like to congratulate our employees contributing to all these achievements.

I believe that we will achieve greater success in the future thanks to the valuable contributions of you all.
Greetings and best regards,

Prof. Mahmut F. Aksit
Chairman & CEO, TEI

DELIVERY OF TEI-TS1400, THE FIRST NATIONAL HELICOPTER ENGINE, AND OPENING CEREMONY OF THE DESIGN CENTER

Celebrating its 35th anniversary while farewell to 2020, TEI has had its name written on the sky with gold letters thanks to creating a touchstone for the Turkish aviation industry.

Celebrating its 35th anniversary while farewell to 2020, TEI has had its name written on the sky with gold letters thanks to creating a touchstone for the Turkish aviation industry.

On December 5, 2020, the prototype of the TEI-TS1400 turboshaft engine is delivered to the Turkish Aerospace for size and mounting tests. Supported by the Presidency of Defence Industries under the Turboshaft Engine Development Project, the prototype will be tested in Gokbey Helicopter. His Excellency Mr. President Recep Tayyip Erdogan, attended the ceremony. In addition to the development of the TEI-TS1400 engine, the Project covers studies to increase knowhow about design and necessary infrastructures for national gas turbines. In this scope, the Opening Ceremony of the Design Center was simultaneously held. When completed, the design centre will have over 11,000 square meters of office space and 3,000 square meters of prototype manufacturing workshop.

The ceremony was held at TEI's Eskisehir campus with the participation of Hulusi Akar, Minister of National Defence, Mustafa Varank, Minister of Industry and Technology, General Yasar Guler, Commander of Turkish Armed Forces, Prof. Ismail Demir, President of Defence Industries, Erol Ayyildiz, Governor of Eskisehir, Muhsin Dere, Deputy Minister of National Defence, and other protocol members, in whom His Excellency Mr. President Recep Tayyip Erdogan attended by live stream from Vahdettin Pavilion.

In the first speech of the ceremony, Prof. Mahmut F. Aksit, Chairman & CEO, TEI, talked about the development stages of stages of TEI-TS1400 engine. Noting that the process beginning from engine design and proceeded with comprehensive stages such as manufacturing, assembly, testing, verification, and certification, Aksit said, “We have established a special team developing engine design tools. Our teams developed over 30 design and analysis software, which makes TEI one of the indigenous engine manufacturers having their software tools.” Aksit stated that they improved engine compartments such as compressors and combustion chambers by using these software tools for the design. “One of the most important technologies TEI has developed is the production of winglets in the hottest area of the turbine module as both casting manufacturing and cooling technology.” Stating that the

manufacture of the engine begins upon completion of the design, Aksit said, “We identified our shortcomings for manufacturing before launching of the project, and we had the infrastructure to produce all parts of the engine as of September 2017. In aviation, you need to certify all of your manufacturing capabilities. As of October 2017, we, with our 52 approved special process competencies, became the world’s first among nearly 4,000 companies.”

In his speech, Hulusi Akar, Minister of National Defence, stated that important steps had been taken in the aviation sector

as well as in all areas of the defence industry thanks to the encouragement and support of our President. Noting that he had visited TEI last year and witnessed the successful TEI-TS1400 engine tests, Akar said, “Today, we are witnessing that this distinguished company has written a great success story.”
"For the strong defence industry and strong army, thanks to our high motivation and the leadership of His Excellency, we continue to work, produce and develop shoulder to shoulder with public and private sectors, foundation companies, and universities. We know quite well that the technology and innovation activities required to develop products so that we can compete in the global market have gone far beyond a level that companies can now achieve with their means. Therefore, companies around the world either develop a strong cooperation model or try to keep up with the spirit of the time by forming partnerships. Following this model, we have been developing various cooperation methods, including partnering with the private sector. We try to meet the needs of the Turkish Armed Forces as quickly as possible. I would also like to express my gratitude to His Excellency, who lead us and enlighten our path, and to everyone who worked hard and made great efforts.”

In his speech at the ceremony, Mustafa Varank, Minister of Industry and Technology, stated that it was a historic day for the defence industry. Noting that Turkey, thanks to the vision of National Technology Movement, is taking firm steps forward becoming not only a user but also a manufacturer of critical technologies, he said, "Today, we are capable of developing products requiring high technology and advanced design skills."
Our national turboshaft engine TEI-TS1400 is one of the best examples of these strivings. This engine was designed, developed, and produced entirely by TEI engineers and technicians. When mass production gets started after the compulsory certification processes, we will avert both one more foreign-source dependency and an annual high technology import of 60 million dollars. TEI-TS1400 is a pioneer of our future successes. Turkey is one of the seven countries being capable of gas turbine engine technology. Today we are also opening a new design center, where we design national engines as a starting point of new success stories."
Stating that TEI's all production and assembly workshops required for the development of gas turbine engine, which is a critical technology, can easily design engines to be used in our national aircraft such as HURKUS and ATAK, Varank said, “Being one of our pride institutions, TEI is moving forward to a much stronger production period thanks to these opportunities. While the per-kilogram value of Turkish exports is currently at $1.50, the same figure is over $50 in the defence industry. The export value of our first national helicopter engine, the TEI-TS1400, is $6,000 per kilogram.” This is the proof of the success of the R&D and entrepreneurship ecosystem that we have been building from the ground in 18 years, and our policies prioritizing value-added production".

Emphasizing the importance of this day for Turboshaft Engine Development Project initiated by the Presidency of Defence

"TEI will turn into a role model in Turkey thanks to the future investments and with acquired capabilities with Turboshaft Engine Development Project”

Industries and carried out by TEI, His Excellency Mr. President Recep Tayyip Erdogan stated that TEI will turn into a role model in Turkey in its field thanks to the future investments and with acquired capabilities during the progress of the project.
His Excellency Mr. President Recep Tayyip Erdogan also said, “At the design center, engineers, design, and R&D units will work much more efficiently and incoordination.” His Excellency stated that their goal is that TEI, the national industrial organization, becomes among the most important players in the sector in the international arena and noted that TEI is now turning into a brand that not only produces engines but also designs, manufactures, and sells them to the world. His Excellency Mr. President Recep Tayyip Erdogan said, “With this project, we are also establishing a very serious test infrastructure that can test engines of this class and other similar classes in Turkey. The infrastructure can also be used in the testing of our higher power class engines such as the National Combat Aircraft Engine.
We will not allow the modern projects experience the same end just like other projects such as Nuri Killigil, Vecihi Hurkus, and Nuri Demirag in the past and sincere initiatives such as the "Revolution Car" (Devrim Otomobili). I hope that we will firmly protect the engine projects of TEI and other organizations to ensure that our country reaches its goals in this field." Congratulating the national helicopter engine and TEI Design Center, His Excellency thanked the members of the Presidency of Defence Industry, employees of TEI, industrialists, academics, and everyone having a role in the development and production projects of the engines. His Excellency expressed his wish to see the engine in the skies as soon as possible after the successful completion of the test.

Following the speech of His Excellency, Turkey's first national turboshaft engine TEI-TS1400 was tested. After the engine test, Prof. Mahmut F. Aksit, Chairman & CEO, TEI, delivered the "TEI-TS1400 Engine Operating Manual" as a memory of the day to Prof. Rafet Bozdogan, Chairman of the Board of the Turkish Aerospace. Then, on the instruction of His Excellency Mr. President Recep Tayyip Erdogan, guests opened the Design Center by cutting a ribbon. Upon delivery and opening ceremony, guests visited and evaluated the Design Center and TEI Eskisehir campus.

PHOTOS FROM THE CEREMONY OF TURKEY'S FIRST NATIONAL HELICOPTER ENGINE TEI-TS1400

Yusuf Erge Air Control Group Commander Air Brigadier, Prof. Fuat Erdal Rector of Anadolu University, Prof. Tuncay Dogeroglu Rector of Eskisehir Technical University, Metin Sarac Deputy Chairman of the Board of Eskisehir Organized Industrial Zone, Prof. Mahmut F. Aksit Chairman & CEO, TEI, Yeliz Cetinkaya Human Resources and Administrative Affairs Director, TEI

Visit by ESAC Board Members: Prof. Mahmut F. Aksit, Chairman & CEO, TEI, Sinan Musubeyli Chairman of the Board of EJS, Adnan Canseven General Manager of Aycan Aviation, Senay Idil General Manager of ALP Aviation, Cumhur Turan General Manager of Numerical Machine, Kenan Isik ICI Founding President.

Murat Ircal Chief Prosecutor of the Republic, Ercan Atasoy Eskisehir Provincial Gendarmerie Commander G. Colonel, Engin Dinc, Police Chief of Eskişehir City, Prof. Mahmut F. Aksit Chairman & CEO, TEI.

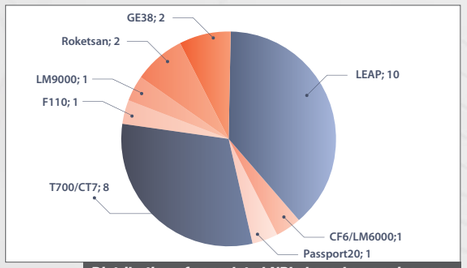
Eskisehir Press

ACTIVITIES
IN 2020

PARTS AND MODULE MANUFACTURING

NEW PART INTRODUCTION (NPI)

In 2020, our company completed and delivered 26 NPI projects to its customers on time. 14 of them were the orders of General Electric, 2 of them for MTU, 2 of them for Roketsan, and 8 of them for the T700-TEI-701D project. 12 of the NPI projects were completed for next generation commercial engine programs such as LEAP, Passport, LM9000. TEI has completed 946 NPI projects total for 42 engine groups until now.



Distribution of completed NPIs based on engine group

OTHER INDIGENOUS ENGINE DEVELOPMENT PROJECTS

TEI-TJ300 Manufacturing of parts for 5 engines was completed and delivered for assembly. In addition, TEI manufactured 75 different engines and test parts required for idle operation tests, compressor and turbine verification tests, performance tests, and rotor dynamic RPM upgrade tests.

TEI-TJ90 Parts of 5 engines for design tests and 11 engines for delivery to Turkish Aerospace have been manufactured and delivered for assembly. For Simple Connected Bed Rotor Dynamic Test Mechanism made about Rotor dynamic, 25 different shafts and 20 different shaft tubes, 10 different legs, 5 different dummy impeller, nut, and turbine parts have been produced.

TEI-PG50 Approximately 50 different parts have been manufactured for design tests and cost reduction projects.

TEI-PD170 Mass production processes got started for 18 engines after their assembly and shipment procedures were completed. Operations for the manufacturing of aluminum engine blocks were successfully conducted. The block will be the first of its kind in Turkey. Within the scope of activities, processes such as flush clean, leakage pressure test, honing for the production were developed.

INVESTMENTS

TEI commissioned the following investments in 2020:

- 2 Vertical Boring Mill
- High-Speed Milling and Corner Crushing Machine
- Small Size Multi-purpose Horizontal Processing Mill
- Sharpening Workshop Central Filtration System
- Induction Braze System
- CSM (Curved Slot Mill)
- Simultaneous Ball Forging Machine
- 2 Fine Surface Polishing (Ultrapolish) Machine
- 225 KV X-Ray System
- Renovation of FPI Station's Door and Rail Systems
- 6 CNC ECM Mill
- CNC Sandblasting Machine
- Rotaplasma Thermal Spray System (TEI-PD170)
- B800 New Entry Quality Station
- Tracer Measuring Device

Commissioning studies for the following investments under the scope of indigenous projects manufacturing workshop have been completed:

- 3D Scanning Technology Measuring Device - Pale Scan Head
- Articulated CMM Measuring Device
- Part Branding Machine
- Sample Polishing Machine
- Ultrasonic Cleaning Machine
- Centrifugal Surface Improvement Machine

Orders for the following benches included in the investment plan were opened and their installation was planned on the specified dates.

- 2 Drying Ovens
- Robotic Paint Booth
- Door and Rail Systems of FPI Station Renewal
- Thermal Spray Machine Robot Upgrade
- Torque Meter Calibrator
- Chemical Processing System
- Oil Cooled Vacuum Furnace.

PRODUCTIVITY

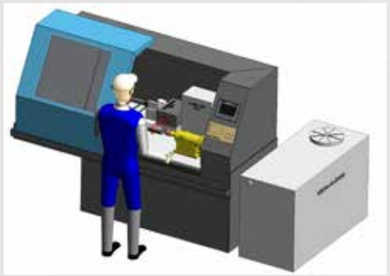
In 2020, TEI improved its total labor hours for the parts by an average of 8.8%, which consists 84% of the total workload.
In 2020, TEI planned the layouts of the benches for the T200 Turboshaft prototype manufacturing workshop. After all, benches were arranged per the plan, all manufacturing workshops were fully designed following the 5S.
During 2020, TEI transformed the following fields per the workflow arrangement and 5S factory applications:

- B800 DP32 Engine Assembly Area
- B800 Engine Assembly Quality Control Area
- B700 Quality Control Area
- B700 Gear Measuring Area
- B700 Flow Test Area
- B300 Heat Treatment Area (in progress)
- B400 Entrance Control Area (in progress)
- B300 Press Machine (in progress)

For B700, LEAP, FOS, Cell parts, the ''Nonconformance Management System'' under the efforts for making Lean Manufacturing applications widespread were engaged.

In 2020, all engineers and leaders working in the departments of the Directorate of Quality and Manufacturing Engineering and Directorate of Manufacturing were given training titled “Problem Solving with A3”, and A3 application started to be used as problem solving technique. Newly employed trainings were given 5S trainings under the scope of orientation trainings. Within 2020, one 5S audit were performed due to the pandemic. As a result of 5S audit carried out, TEI was awarded the B200 Balancing area, 3 star 5S flag as 5S champion.

NEW TECHNOLOGIES AND AUTOMATION APPLICATIONS



In the scope of TEI's operations in 2020 Digital Factory Applications, following works have been done:

- Digital announcement board application improvement works
- Estimated delivery time calculation report
- Automatic character numbering in TEI design technical drawings
- Preparation of operation file from NX data (in progress)
- Digital quality warning system
- QCI system and NC Management system integration

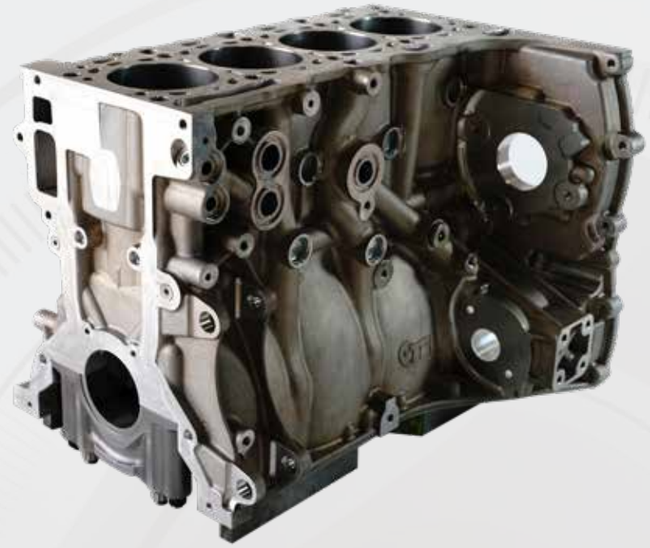
Thanks to the improvements and investments in 2020, TEI acquired the following new production capabilities:

- Developed New Induction Braze System provided the quality checks that TEI could not follow before for the manual torch braze operation. In this way, TEI avoided operator-induced variabilities and could repeat processes with the same statistics.
- “Form Process with Independent Hydraulic Propulsion” capability was obtained as an alternative to the Hydroform process for the form of parts having a long tube shape. With the system designed and manufactured in TEI, press movements were used to meet the high forces required to keep the mold closed, and compression and forming were obtained from a separate hydraulic system in the mold. Thanks to the newly designed mold and hydraulic system, TEI started to use 300 tons of conventional hydraulic press instead of hydroformed press, which was expensive.
- Central cutting oil filtration and cooling system were commissioned for 10 mills in the Tool Sharpening Workshop.With the new system, space saving within the workshop, energy saving, stability in the sharpening process and cost benefit for benches to be procured in the future have been ensured.
- The 6071T76G03 Compressor Case part was coated for the first time in TEI using an internal diameter thermal spray gun. This part was coated abroad in the past.
- Turbine pale surfaces needed in indigenous projects were coated for the first time using the thermal barrier coating thermal spray method. As this coating method has widespread usage in the energy sector, it is estimated that this ability can create a new activity field for TEI in the future.
- The removal processes required for the repair of the carballoy coating in the wing parts belonging to the Navy Forced Command were carried out at Sink EDM benches.
- Thanks to the reset apparatus designed for simultaneous shotpeen operation of blisk parts of GEnx engine program, operations times were reduced, and capacity gain was achieved.
- For the first time within TEI, Turboshaft Stage-1 and Stage-2 PT Blade parts Z-Lock and Seal geometries were provided to finish geometry with Sink EDM process.
- Consumable’s consumption was reduced by ensuring that the original and expensive bench spare parts of wire erosion benches were produced at a more cost-effective with 3D print within TEI.
- To protect T700 engine blisk parts against corrosion, F50TF62 “Sealed Aluminium Coating for Airfoils" coating was applied for the first time.
- For use on the BP800 FPI Station, an Electrostatic Developer application unit was designed,manufactured, and put into use.
- Within the scope of the DP22 national engine block development project, a special wireless measuring tool was developed and put into use with a Turkish company supplying locally produced measurement systems for diameter measurement from the 180º region that can not be measured by CMM and classical methods due to geometric constraints.
- To improve measurement capabilities and make faster measurements for indigenous engine projects, the Airfoil Scan Head specially developed for aviation applications was adapted to the 3D Measuring machine. With this investment, the prepaint application process was removed in casting and additive manufactured parts, and measurements were accelerated up to 3 times.
- With the commissioning of the articulated arm cmm device, the waiting times during the correction of casting and additive manufactured parts were eliminated.
- By performing different media adaptations at the centrifugal surface improvement bench, flow surfaces of the additive and casting airfoil, damper, and NVGs were improved.
- Capability of tie shaft production under the General Utility Helicopter Project and of production of output main shaft and tie shaft parts under TEI-TS1400 Turboshaft Engine Development Project were gained. Deep-hole drilling and long hole boring, threaded spline hobbing process was performed in the production of these parts.
- By commissioning the relevant investment to TEI, ultrasonic washing capability is used for the manufacturing workshop of indigenous engine projects to purify and clean the parts of greases, cutting fluids and Atos scanning paint they are exposed during operations.
- Fuel Injector Test Device investment and adaptation was ensured in order to gain complex test capability of injectors, which are contained in combustion chamber module and which are used for fuel spraying.

TEI-PD170 ENGINE DELIVERED TO BAYKAR

An engine and propeller were delivered to Baykar Company. While the tests of the engine continue successfully, the process of integration to the TB3 platform is planned to continue in 2021.

TEI-PD170 NATIONAL ENGINE BLOCK



After comprehensive studies of TEI and Erdokum on engine blocks, an agreement was signed. And the blocks were tested successfully. TEI-PD170 engine block is the first Turkish aluminum engine product locally designed, cast, processed, and assembled.

PRESIDENCY OF DEFENCE INDUSTRIES (SSB) ACCEPTED 5 TEI-PD170 ENGINES

Following the successful compulsory completion tests, SSB Acceptance Committee commissioned 5 TEI-PD170 engines developed under the Operational UAV Engine Development Project.

HUMAN RESOURCES PROCESSES

"CAREER AND OUR PROJECTS IN TEI" LIVE BROADCAST EVENT ORGANIZED

On December 3, "Careers and our Projects in TEI" event was organized on TEI Youtube and Twitter accounts to explain TEI's current projects and answer questions about TEI. Prof. Mahmut F. Aksit, Chairman & CEO, TEI, Ahmet Findik, Turboshaft Engines Director, Yeliz Cetinkaya, Human Resources and Administrative Affairs Director, and Dr. Mehmet Demiroglu, former R&D Director attended. Enjoying the interview, the audience took an online quiz at the end. Apple Airpods were given as gift to the first three audiences who answered the questions the fastest and most accurately.

TEI TECHNICAL TRAINING CENTER

In the second quarter of 2020, the installation of the Technical Training Center (TEM) got started in cooperation with the Directorate of Human Resources and the AIT&MRO Directorate. Technical Training Center started on August 27, 2020, with the first course by Murat Ilker Celik, TEI AIT&MRO Director.

Technical Training Center continues its courses by 18 internal instructors to the employees of directorates on 37 different subjects. Courses will cover 20 business days per person.

PROGRAM OF DEVELOPMENT ACADEMY 2020 STARTED

Employees with the required criteria started with the “Development Academy 2020” Program's “Wizards of Communication” session. Participants will graduate from the program in 2021 upon completion of 6 modules and 3 Educational Follow-up Monitoring Systems.

ONLINE ORIENTATION PROCESSES MANAGED FAST AND EFFECTIVELY

Due to the pandemic, TEI had to organize the "Orientation Program for New Employees" online. After the Online Orientation, TEI organized a “Welcome Dinner” for the new employees at its guest house. TEI Human Resources and Administrative Affairs Director Yeliz Cetinkaya and TEI Human Resources Manager Mustafa Kemal Baldoktu had dinner with the new employees.

2020 "FLY YOUR CAREER" SUMMER INTERNSHIP PROGRAM

The internship is one of the important parts of their education for students. Being aware of this, TEI applies a customized internship program for students for them to get information and skills on the aviation world. With this program, students are offered a model of taking a more effective role in business processes during their internships. By this means, it is aimed that TEI interns experience business life and gain experience.

In the program, where personalized coaching opportunities are provided, interns were allowed to enrich their professional skills by benefiting from coaches' knowledge. Measures taken due to new coronavirus (Covid-19) epidemic and 2019-2020 academic year, TEI summer internship program started by applying Covid-19 test kits by TEI Occupational Physician to intern students for the health of students and employees, and students spent the first week of the internship receiving orientation programs in the training environment specially prepared for them at TEI Picnic Area. Mahmut F. Aksit, Chairman & CEO, TEI, visited the students and thoroughly informed them.

After the orientation program, TEI interns had the opportunity to get to know both the aviation sector and TEI more closely. The program continued with summer internships regarding TEI Interview Management Information, interview simulation, case analysis study, and TEI Competency Information programs. "FLY YOUR CAREER" for the Summer Term on June-September period was organized as 4 semesters. In addition to Covid-19 tests, intensive Covid-19 information was given according to pandemic requirements. In the first week of the program, "Intern Orientation" was performed according to the pandemic conditions in the area specially prepared for TEI interns at TEI Eskisehir campus, and interns were provided with technical and personal development training by TEI's experienced staff.

At the end of the orientation program, the event was completed with a fun Kahoot game, and students completing the game were awarded. Interns were also given access to online training on the TEI distance education platform during the program. The summer internship program was completed with the high satisfaction of the interns, accompanied by experience sharing and mentorship of the coaches assigned to them.

6-SIGMA TRAINING ORGANIZED AT TEI

As a pilot project, 4 sessions of “6-Sigma Green Belt” training were organized with the participation of team members working on Piston Engines projects.

WHAT IS 6-SIGMA?

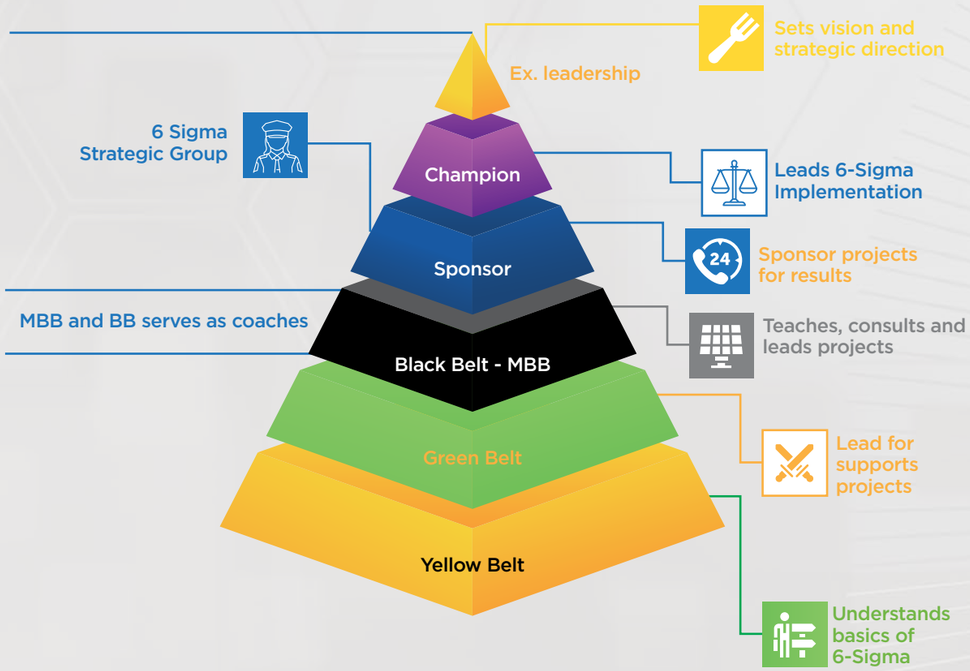
6-Sigma is a method that provides organizations with tools to improve the capabilities of business processes and their operational productivity. The increase in performance and productivity and the decrease in process variation provide the following gains for organizations.

- Reducing Problems / Defects
- Cost Reduction and Increase in Product Profit
- Employee Morale and Quality of Products / Services

6-SIGMA BELT COLORS

Belt colours are signs of understanding the level of expertise. At the project level, the 6-Sigma belts come in different colours: Yellow, Green, Black, and Master Black Belt.

Referencing the "belts" by their colour is a simple and effective way to quickly understand the skill set and level of experience.



OPENING CEREMONY OF TECHNICAL TRAINING CENTER UNDER TEM-R&D & TURBOSHAFT DIRECTORATES

Implementation of 2nd Technical Training Center project got started in the last quarter of 2020 to include R&D and Turboshaft Engine Directorate. Directors of the R&D and Turboshaft Engine Directorates were among the participants of the first course by Erinc Erdem Principal Engineer on October 26, 2020. The first stage of the TEM-R&D project was addressing new employees. In this context, 25 internal instructors lectured about technical methods to employees of the directorates on 25 different topics. Each participant had 36 hours of training. Works for 2nd stage of TEM-R&D training to cover senior employees started in the last quarter of 2020.

MOMENTUM PROGRAM 2020

“Momentum Internal Instructor School" project got started to increase the competencies of the expert staff who are internal instructors at TEI. The first training of Momentum Internal Instructor School was "Trainer's Tranier". Training will continue in 2021, as well.

DISTANCE TRAINING PROGRAM (LMS)

With the awareness of the importance of training and development, LMS infrastructure has been renewed by rapidly adapting to pandemic conditions. Thanks to the updated system, all employees were able to access their training from anywhere at any time, they wish. 55,000 hours of training were assigned through the system, which was started to be actively used in the 2nd quarter of 2020. System improvements continue according to the needs of TEI employees.

TEI'S BUILDING ENTRANCE RENEWED

TEI renovated its main building entrance. At the entrance, the company displays indigenous engines designed, developed, and runned for national platforms, parts manufactured by using 53 different special process methods for national and international engine programs and technology development studies.

"WE PROMISED!" RELASED

The film named “We Promised!”, which describes the current studies in TEI’s fields of activity and the indigenous engines it has developed, was released.

THE WORKSHOP ON GOAL ACHIEVEMENT FOR 2019, FUTURE FORECASTS IN THE INDUSTRY, AND IMPROVEMENT AREAS FOR EMPLOYEE COMMITMENT HAS BEEN HELD

A one-day event under the theme of “Goal Achievement for 2019, Future Forecasts in the Industry, and Improvement Areas for Employee Commitment” was held on March 10, 2020 at Eskisehir Tasigo Hotel with the participation of senior management and managers of TEI.

In the event, Prof. Mahmut F. Aksit, Chairman & CEO, TEI, Ahmet Kain, Programs Director of TEI, and Yeliz Cetinkaya, Human Resources and Administrative Affairs Director at TEI, made presentations to the managers of TEI.

After the presentations, a workshop was held on the corporate development areas determined for TEI. In the workshop, the executives shared the problems they notice about the topics reported to them and the solution suggestions thereof. The development areas determined and the solution suggestions were scored and ranked in the order of importance by the participants. Within this context, priority analysis was carried out after the workshop, and improvement projects for the issues with the highest priority were initiated.

THE SLOGAN CONTEST OF "TEI'S 35TH ANNIVERSARY"

A contest held to find a slogan that will mark the 35th anniversary of TEI was concluded. The slogan by Metin Cetin from Manufacturing Milling Management, “At 35th year with the love of the first day”, and “Pioneer in Technology, Leader in Aviation” by Gizem Ezgi Ugur Solakoglu from Technology Programs Management has been chosen as slogans of our 35th anniversary.

TEI HAS BEEN AWARDED EMPLOYEE ENGAGEMENT IN 3RD TIME

TEI received a special award 3rd time in succession at the Best Employer Award Ceremony organized by Kincentric, according to the results of the Employee Engagement and Satisfaction Survey conducted as a result of its studies in the field of human resources and the rising engagement trend. TEI Employee Engagement and Satisfaction Survey results were launched in December.

TEI, STAR OF THE "I AMCHAMPION" AWARDS

I AM CHAM PION AWARDS

In the “I AmChampion” awards organized by the American Companies Association, TEI has been awarded in the categories of "Turkish Company Most Contributing to Exports from Turkey with The Best Digital Transformation" and "Turkish Company Most Contributing to Exports from Turkey with the U.S. Partnership".

TSE'S SAFE PRODUCTION CERTIFICATE TO TEI

TEI becoming an examplary company during the Covid-19 pandemic shaking the world in 2020 was awarded the Covid-19 Safe Production and Service Certificate given by TSE for its great care and measures with a disciplined approach. The certificate was presented by Erol Ayyildiz, Governor of Eskisehir, to Prof. Mahmut F. Aksit, Chairman & CEO, TEI.

TIM DECLARES "TOP 1000 EXPORTERS OF TURKEY 2019"

The results of the “Top 1000 Exporters of Turkey 2019” research were announced by the Turkish Exporters Assembly (TIM). According to the results of the research, TEI ranked 39th after rising 4 ranks compared to the last year. In addition, TEI ranked 2nd in the Defence and Aviation Industry sector.

İMİB TIM TÜRKİYE İHRACATÇILAR MECLİSİ
2019 TÜRKİYE'NİN İLK 1000 İHRACATÇI FİRMASI
TOP 1000 EXPORTERS OF TURKEY

TEI WAS SELECTED AS 9TH COMPANY SPENDING MOST TO R&D IN TURKEY

Turkishtime
AR-GE 250 2019
Türkiye'nin Ar-Ge Harcamaları En Yüksek 250 Şirketi

In the "R&D 250" research organized by Turkishtime, TEI became the 9th company spending most on R&D.

SAFETY ANALYSIS PERFORMED FOR SAFETY COMPLIANCE DISPLAY AT AN ENGINE CONTROL SYSTEM DESIGN OF AVIATION TURBOSHAFT ENGINE

WHO IS KUBRA MUTLU

Engineer
Airworthiness and Certification Management – TEI
Worked from 2018 to 2021.

WHO IS MUJDAT ASLAN

Technical Leader
Piston Engine Management - TEI
Worked from 2014 to 2021.

ABSTRACT

The purpose of developing a type - certified aviation engine requires to meet the safety requirements notified by the aviation authorities. In order to comply with these requirements, a Safety Assessment process is carried out and the outputs are presented to the authority. Both quantitative and qualitative safety analysis outputs are produces specific to Engine Control System, which is one of the most critical systems for an aviation engine. In line with these outputs, if the fact that no unacceptable safety critical fault status is caused and that this status is sustainable are proven, there would be no obstacle to obtain a type certification for safety. In this statement, safety analysis carried out to show the compliance with the requirements specified in paragraph CS-E 50 that was written specific to control system of CS-E (Certification Specifications for Engines) where certification requirements are transferred for Engine Control System of an engine which serves a civilian purpose and is in the type certification process. Under the guidance of SAE ARP4761, Functional Hazard Assessment, in which fault status of all the functionalities of the system are evaluated and their importance are rated, is mentioned, and the relationship between the item development assurance level (IDAL) and safety analysis is stated, and information is given with regard to guideline documents that are necessary to be followed for compliance with the DAL level.

Keywords: Helicopter, Engine Control System Risk Analysis, CS-E 50 Requirement Compliance Verification

1. INTRODUCTION

Prior to using software and complex electronic hardware systems in aviation, it was easy to examine, analysis or test the features of the system. Error rate was assigning for the system and the system safety methodology was being fed.

With the development of the Engine Control System, assignment of fault rate for systematic faults at the design, application and production phase of complex systems has become difficult. The reason for systematic faults are versatile functionality load that is usually expected from the system to carry out under certain conditions. The behaviours of the systematic faults may not be directly predicted and numerically measured as they cannot be modelled by the distribution of fault probabilities. The reason for this is that systematic fault behaviours cannot be characterised by a certain probability density function. [1]

Safety assessment processes covers production of requirement and verification during the engine development activities. Since it is impossible to fully determine the accuracy of the requirements and design application in practice, it is necessary to verify that integrated or complex systems such as Engine Control System are free of faults sufficiently. [2] It may be qualitative or quantitative safety assessment processes. [3] In the integrated system, main goal of the safety assessment process are to define appropriate requirements for fault status and to bring the safety requirements to its final status in a way to meet the requirements. The

safety assessment process begins with concept design, after which safety requirements are derived. With these requirements, the changes are reflected to the design. New requirements are derived as the design changes. Even if the safety assessment process lasts throughout the product life cycle, this process ends with the verification that safety requirements of design are met even if this process.[2] Most system faults are caused by misunderstanding of the requirements rather than misapplication of them. For software and hardware requirements, this problem requires a review of system-level requirements and the requirements that are broken from the system level to software and hardware level in line with a development organization. [1] Due to these reasons, a different method was needed to guarantee the behaviour and characteristics of the systems and parts.

With the Development Assurance, system (or part) behaviour and characteristics have been guaranteed. This assurance approach is based on extensive definition of system needs specific to product or process and on the management of requirements during the system life cycle. In addition, it provides a process for verifying the specified design objectives. Minimum safety requirements according to the designed aircraft type are specified at the flight availability standards, which are established by aviation authorities. When other product requirements under the flight availability and qualification are met, a safe aircraft is deemed to have been designed meeting the customer needs. In order for an aircraft to meet the mission requirements expected from it, it must first be available for flight. In AC 25.1309, the process on the nature of safety studies required by the requirement and on when these studies should be carried out are explained. [4] In order to meet this requirement, the guide documents that are accepted by the authorities are SAE ARP 4761 and SAE ARP 4754. These guide documents includes the methods for how to adapt to the safety requirements required for flight availability in design. [5]

With guide contents provided at DO-178B / ED-12B and DO-254 / ED-80, specified design requirements is enabled to meet the assurance levels that should be meet specific to software and hardware.[2] Development assurance level assignments depend on classification of fault conditions. The safety analysis process is used in conjunction with the development assurance process to identify fault conditions and violence classifications in order to obtain necessary meticulosity level for development activities.

As a result, the safety assessment process identifies the fault conditions used to obtain meticulosity level for safety analysis process, development activities.

2. COMPLIANCE DISPLAY TO CS-E 50 ENGINE CONTROL SYSTEM

CS-E includes flight availability requirements for issuance of engine type certification.

These requirements include the requirements that should be met to design a safe Engine Control System in article CS-E 50.

In this study, it is explained how to display compliance for a few of the CS-E50 requirements. [6]

Paragraph CS-E 50 consists of 11 sub-articles. In Chart 1, sample sub-articles are given in which it is demonstrated how to carry out compliance display study. In order to avoid a shift in meaning, the original requirements are presented.

CS-E 50 Engine Control System
(c) Engine Control System Failures. The Engine Control System must be designed and constructed so that:
(1) The rate for Loss of Thrust (or Power) Control (LOTC/LOPC) events, consistent with the safety objective associated with the intended aircraft application, can be achieved;
(2) In the Full-up Configuration, the system is essentially single Fault tolerant for electrical and electronic Failures with respect to LOTC/LOPC events;
(3) Single Failures of Engine Control System components do not result in a Hazardous Engine Effect;
(4) Foreseeable Failures or malfunctions leading to local events in the intended aircraft installation, such as fire, overheat, or Failures leading to damage to Engine Control System components, must not result in a Hazardous Engine Effect due to Engine Control System Failures or malfunctions.

Chart 1. CS-E 50 Engine Control System Requirement Content

For Engine Control System requirement (c) (3) given in Chart 1, the methods for detailed analysis through Helicopter Engine Engine Control System's sample functions and for process of creation of compliance evidence are explained in the following sections.

3. COMPLIANCE DISPLAY TO CS-E 50 ENGINE CONTROL SYSTEM (c) (3) REQUIREMENT

In the Requirement main article (c), it is emphasized that the Engine Control System should be designed to meet the requirements given in (c) (1), (c) (2), (c) (3) and (c) (4) and not to cause hazard engine affect due to fault and faults. The first document by which the fact that a design is in compliance with the requirement is shown to the authority is definition documents. However, in order to verify the information included herein, analysis, test, equipment feature document, etc. may be prepared and a reference may be given from the design definition documents.

What is required by (c) (3) this requirement is that the single fault in Engine Control System components will not lead to the dangerous engine effect. Therefore, all fault situations that may occur depending on the Engine Control System design should be determined and it should be proven that probability of occurrence according to the fault status

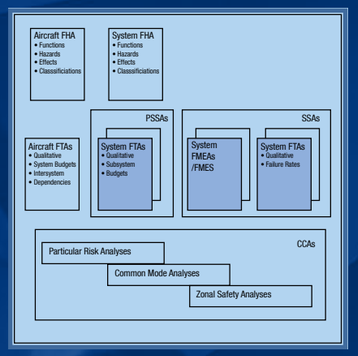


Figure 1. Overview to the Safety Assessment Process [3]

Figure 1 shows the connection between FHA, PSSA, SSA.

No Document
1. Functional Hazard Assessment (FHA): With a top-down deductive approach,all possible fault situations that can be related to the Engine Control System functions and that are for loss of functionality of the system or its operation with fault are defined, and the worst fault situation that are related to its operating conditions and its environment are taken into consideration. Classifying these fault situations constitutes the basis of safety requirements that the system must meet.
2. System Pre-Safety Assessment (PSSA): It is the document in which itis foreseen that the design may meet the safety requirements that are determined in FHA study. It is a systematic examination method that examines the offered system architecture to determine the type of faults that may cause functional faults identified by the FHA. Error tree analysis (FTA) shows how the system can cause fault situations that are determined in FHA. Via FRAs, the lower-level safety requirements (falling on the engine control system part) are determined. As a result of FTA analysis, part-level design assurance level (IDAL) is assigned.
3. Common Cause Analyses (CCA): It consists of the Zonal Safety Analysis (ZSA), Particular Risk Analysis, (Common Mode Analysis), which are prepared to display that redundancy of equipment/systems shown as being backed up with FTA analysis actually exists and to show that probability of other possible fault situations other than the fault situations determined at FHA is acceptable level. As a result of CCA analysis, requirements for separation of parts, external threats and common mode faults are derived at the system and part level.[3]
4. Fault Modes and Effects Analysis (FMEA): FMA study on part level is conducted to support the fault rates of fault modes in FTAs / CCAs.[3] Also all fault modes at part level constitute the fundamental event of FTA operation. Only single faults are found in FMEA study, and verification is carried out at system level by providing input to the FTA.
5. System Safety Assessment (SSA): SSA is a bottom-up study conducted in order to be able to verify that design safety requirements are met. Proof indicating that the system complies with the safety requirements established as a result of FHA and PSSA studies will be given in this document.

Chart 2. Safety Analysis Document List to be Prepared for Displaying the Compliance With CS-E 50 (c)(3) Requirement.

criticalities is acceptable. For this, a safety process should be conducted in an accurate and planned manner.

4. ENGINE CONTROL SYSTEM SAFETY ANALYSIS

Within the scope of the CS-E 50 (c) (3) requirement, safety analysis will be carried out through the “Power Turbine Over-speed Protection” function, which is a standard Engine Control System function used in turboshaft engines.

5. SAMPLE FHA STUDY FOR POWER TURBINE OVERSPEED PROTECTION OF ENGINE CONTROL SYSTEM

In FHA study, safety impact of each function, which fails anywise, functions or malfunctions at an unexpected time, is evaluated and classified. As a result of fault scenarios evaluated, the requirements are established and the effects of the faults are limited.

The function for provision of protection of power turbine over speed is the function where MKS’s power turbine prevents the over speed by interfering with the fuel. The worst case for full or partial loss of this function was considered and some scenarios was created. Chart 3 indicates the scenarios for full and partial loss of the function. The sample FHA study is given in Figure 2.

1. The full loss of the function to control power turbine over-speed: In case of mechanical damage due to vibration in the power turbine speed sensor, the status for power turbine over-speed cannot be identified and fuel flow will not be reduced. As a result of this fault, the power turbine disc cannot be protected safely, and the power turbine shaft will be broken.
2. The partial loss of the function to control power turbine over-speed: Inability to identify the power turbine (PT) revolution increase and to control the fuel valve position at the desired precision and inability to keep the power turbine revolution within its limits were examined. In this fault type, orientation of the rotating parts will be disturbed, bearing internal clearance may be closed with the effect of centrifugal force and PT shaft may be broken. Also, shaft gear structures cannot be broken and transmitted to torque PT shaft taken from discs. Engine’s structural integrity will be impaired. (c) (3) the requirement demands a proof that a fatal fault does not consist of a singular fault that may be experienced in the system. The related safety requirement has been established from the faults identified as fatal at FHA.

Chart 3. Scenarios for Faults of MKS Power Turbine Over-Speed Control Function.

The sample is given in chart 4.

Sample Requirements
1. The power turbine speed sensor will be mechanically/electrically backed up.
2. Valves in the fuel system that will prevent over-speed will be mechanically fault-tolerant.
3. The power turbine over-speed limits will not be exceeded.
4. The fuel sizing valve position will be traceable.
5. Fuel with irregular flow will not be sent instantly with any revolution instability or maneuvering loads.
6. There will be no time delay when checking the fuel valve position.

Chart 4. The Safety Requirements Established for Hazardous Fault Case of the Sample MKS Function that Has Been Examined At FHA.

Nu	Fonk	Error Status	Flight Phase	Effect of Error on Aircraft / Crew	Danger Level	Supporting Material	Validation
Ensuring Flight Safety	Providing Power Turbine Overspeed Protection	**Fails to operate - (Full loss)** This fault condition is a fault condition where the function of providing power turbine overspeed protection is completely lost.	All phases	Non-containment of high energy debris Deterioration of structural integrity **Determination Method:** Engine power indicator, PTIT&T45Sensors, Ng and Np Sensors **Flight Crew Action:** OEI emergency procedure and emergency landing procedure	Dangerous	CS-E	FMEA PRA FTA
		Inadequate operation - (Partial loss (including corrupted)) This fault condition is a fault condition where the function of providing power turbine overspeed protection is partially lost and is operating erratically.	All phases	Non-containment of high energy debris Deterioration of structural integrity **Determination Method:** Engine power indicator, PTIT&T45Sensors, Ng and Np Sensors **Flight Crew Action:** OEI emergency procedure and emergency landing procedure	Dangerous	CS-E	FMEA PRA FTA

Figure 2. Engine Control System Sample FHA Study

6. SAMPLE FAILURE MODES AND EFFECTS STUDY FOR POWER TURBINE SENSOR

Power Turbine speed sensor measures the PT (Power Turbine) rotational speed, and the status of over-speed is checked via PT speed sensor. In the FMEA study, fault modes occurring due to part-based fault reasons were subject to the study, and the effects of fault modes on part, interfaces and engine were evaluated. All possible fault modes for the Engine Control System will be identified and FMEA study will be conducted in order to show how each fault will affect the engine. Then, a safety assessment will be carried out by considering these fault modes and their effects, and critical parts will be identified.

The sample FMEA study is given in Figure 3 for Power Turbine speed sensor. The fault modes from FMEA study will feed Fault Tree Analysis, and these fault trees will be used to indicate that all possible fault modes have a sufficiently low probability to be able to fulfill the specified requirements. If this analysis indicates that the system will not meet the requirement, the system is needed o be re-structured. This is usually possible by ensuring the redundancy of sensor or actuator. With FTA analysis, fault rate will be assigned for all fault modes that may lead to a hazardous effect. Depending on the criticality of the helicopter platform, DAL A level was assigned by the platform. When considering the faults that may happen in MKS, MKS will meet the probability target of 1.0E-9, equivalent of DAL A level, so that the faults do not lead to a fatal effect. In case the probability of the specified top event is not met, the MKS architecture will be changed.

LD	LOWER SYSTEM GROUP	PART DESCRIPTION	FUNCTION DESCRIPTION (PART FUNCTION	POSSIBLE ERROR MODE	ERROR CAUSE	ERROR EFFECT			ERROR DETECTION METHOD	STRENGTH
						LOCAL EFFECT	EFFECT AT A HIGHER LEVEL	FINAL EFFECT		SAFETY
001	Engine Control System	Power Turbine Speed Sensor	Measuring the Power Turbine rotation speed	No Output	1. Breakage of the probe part of the sensor 2. Breaks in the wiring 3. Pin dislocation by connector 4- Short circuit condition by the connector	Cycles Cannot Be Measured	Extreme Acceleration	Structural Integrity Deterioration	Error Code	Dangerous
002	Engine Control System	Power Turbine Speed Sensor	Measuring Power Turbine Rotation Speed	Opened	1. Output of sensor pins by connector 2. Breaks in the wiring					Dangerous

Figure 3. Sample Possible Fault Modes for Power Turbine Speed sensor

7. SAMPLE COMMON CAUSE ANALYSIS (CCA) FOR POWER TURBINE SENSOR

Common cause or common mode faults have been found with CCA, and the designers have been directed toward strategies that eliminate the probability of faults. CCA will feed the FTA to identify the conjunction factors that can cause that component faults potentially become interdependent. As part of the Engine Control System development project, compliance verification was made for safety requirements specified with certification requirements stated in CS-E. System requirements with regard to redundancy and independence between the functions have been established. Tools have been provided to verify independence between functions, systems, or parts, or to identify certain dependencies. In particular, CCA has identified single fault modes and external events that can lead to hazardous engine effect. It will be shown that CCA safety requirements are met with design measures. In Chart 5, external faults that may cause fault in power turbine sensor are sampled and a checklist is created.

Questions
1. Are the cables involved in the control and the cables used in monitoring separated from each other?
2. What is degree of effect of the maximum temperature specified for wiring strength on continuous operation conditions?
3. Will electrical cable bundles be kept together to distinguish fuel lines and electrical lines?
4. Are the distances between electrical lines and hot zones at acceptable level?
5. Is the distance between electrical lines and lines carrying flammable fluid at acceptable level?
6. Is the wiring system physically separated in the redundant systems?
7. Does the design allow incorrect installation of components or of their wiring?
8. Are measures being taken against the road fault followed by the cable in the wiring system? (Standards, etc.)

Chart 5. Sample CCA Study Regarding Power Turbine Speed Sensor Wiring

Safety Analysis that should be carried out in order to fulfill Fault Tree Analysis are given in Chart 4.

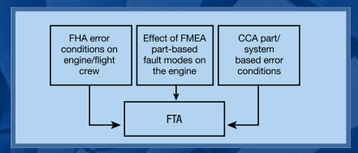


Figure 4. Studies that Will Feed Fault Tree Analysis

8. ENGINE CONTROL SYSTEM ARCHITECTURE

The Engine Control System consists of two Engine Control Units (MKU). Engine Control Avionics architecture is based on the ability of MKUs to read each other's inputs and their outputs. MKU, which is active and placed on engine control, uses its own sensor information and drives its own actuators. There will be no redundancy transition in sensor and actuator information/health losses. As shown in Chart 5, active MKU will continue to control the engine with other MKU's healthy actuator. In case MKU 1 sensor is lost or identified not to have come out in healthy situation, the relevant sensor information of MKU 2 will be used by MKU 1 and the engine will be controlled. There will be a redundancy transition in case of fault/lost of MKU's processor. Now the other MKU will be active and control the engine. [7]

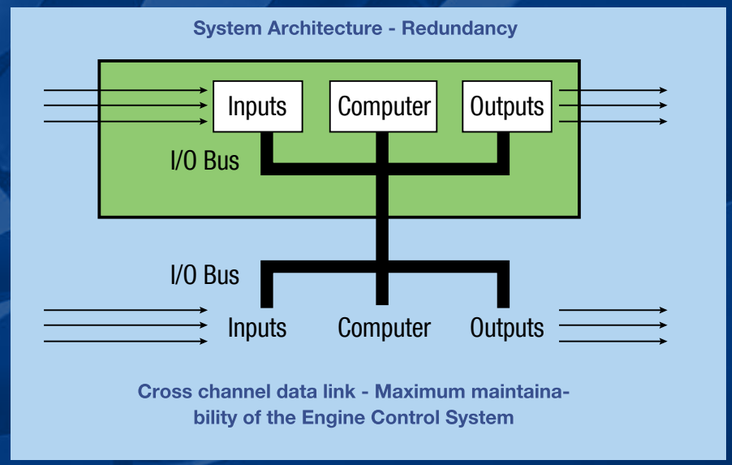


Figure 5. Engine Control System Architecture [7]

9. CONCLUSION

In this document, Engine Control System of the turboshaft engine, developed by TEI, safety analysis carried out under its certification process and the analysis methods applied are mentioned. In this study; FHA, FMEA and CCA analysis were carried out through a sample function of the Engine Control System in order to display the compliance with CS-E 50 (c) (3) requirement. Forecasts on FTA analysis that will be fed with all fault modes existing as a result of analyses performed have been shared. Within the scope of these analyses, information about the evolving design architecture was given.

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ROOT CAUSE ANALYSIS METHODS FOR THE DESIGN OF AVIATION PARTS

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ABSTRACT

Failure modes, which couldn't be detected during the design phase have the crucial potential on the quality of mature products. At first glance, the impression of the quality failures may be underestimated, before the mature design of aviation parts are implemented to production. But these failures may cause some problems in aviation safety and reliability. Therefore, the potential failures during the project design and development phase should be investigated by root cause analysis and defining the precautions both increase effectiveness of design and quality of the outputs.

The aim of this study is, emphasizing the importance of root cause analysis on the design of aviation parts, and stating the analysis methods, which have been used mainly. In the scope of this effort, aviation regulations are researched which encourages the root cause analysis accordingly, related methods are evaluated for the resolutions. The common methods are classified regarding the hazard review of the failures and explained to point out for the researchers.

Keywords: Root Cause, FMEA, Aviation.

1. INTRODUCTION

All of the parts have a designation phase as input and keep the features throughout their product life-cycle. Desired quality may be sustainable, on condition that the risks of the failures are disappeared and mitigated.

Risk analyses support the root cause analysis and provide the finding out solution easier as proactive investigation. For the parts, Failure Mode and Effectivity Analysis (FMEA) has been used and all of the factors are classified and mitigated before the realization process.

The affection of the risks which are coming from the non-factors can't be tolerated for the parts of aviation. In this way, root cause analysis makes the iterations minimum, on the design and sustain the safety and the reliability of the aircraft and lessons learned items are crucial experiences for the main producers.

The aim of this study is to indicate the importance of the root cause analysis methods especially according to aviation regulations and famous producers. Accordingly reviewing all of the efforts with examples from the aviation sector, the root cause analysis, methods are generally classified depends on the criticality of the failure as minor, major and hazardous. This provides the main methodology and perspective for the researchers.

There are a wide variety of researches about root cause analysis for aviation some of them are presented as follows.

Washington et al. made a study about investigating safety system uncertainties for the complex aviation systems which are named Remotely Piloted Aircraft Systems (RPAS). The existing aviation safety systems are needed to develop and the aim of this research is to develop more sustainable and reasonable regulatory outputs determination via System Safety Assessment (SSA). The SSA process and outputs are analyzed in the purpose of improving the safety of RPAS. The analysis has been revealed by using a Bayesian Belief Network (BBN) which the method is using for the root cause analysis via risk-based approach. All of the failure determination have been compared, from Federal Aviation Authority (FAA), European Union Aviation Safety Authority (EASA) and North Atlantic Treaty Organization (NATO) regulatory bodies. In the conclusion of the study, by Bayesian Belief Network failure condition severity classification is handled and it is pointed out that risk-based approach supports RPAS to be more systematic and objective particularly for emerging aviation systems. [1]

Freitas et al. made an investigation to find out failure analysis of the nose landing gear axle of an aircraft which landing gear can not work during the landing and cause the serious accidents. The reliability effect of this part is so crucial. So, the finding root cause analysis duration was supported numerical and experimental analysis. The Finite Element Analysis (FEA) was carried out and an electron microscope was used for the surface of fractures. The optical and scanning electron microscope analysis results are agreed on with numerical investigations. In conclusion, it was found that the failure occurred by overloading both shear and bending stresses, due to confronting a huge

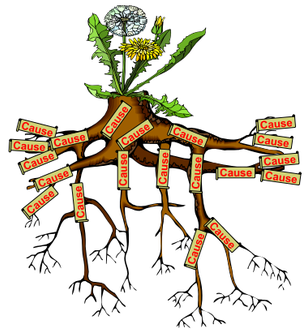
load on nose landing gear instead of main landing gear throughout the aircraft landed. The nose landing gear material will be converted into more durable high alloyed steels instead of low alloy steel. The root cause analysis was handled by verifying potential causes by numerical and experimental analysis via classifying parametric data. [2]

Silveira et al. made a root cause analysis for the failure of the high-pressure turbine blade failures whose material is hardened nickel base alloy. During the analysis phase, elecron microscope is scanned for the analysis with microstructural examination. The analysis was performed for the first blade, which was due to thermo-mechanical fatigue which the internal cooling cavities was started. It was found out, the carbides with cracked and primary have an important role for the potential of failure. The first blade has the fatigue of thermal and mechanical side with tendency to creep. The precautions should be defined and implemented during the design phase. [3]

Rabcan et al. made a study about deriving an algorithm for a diagnosis which is non-destructive concerning the signals. This algorithm is encouraged to solve blades of gas turbine related with signal of vibration after a non-destructive signal and classify it as hazardous and normal. To find out the problems on aircraft engine blades, the diagnosis is ordered to Fuzzy Decision Tree (FDT) that cumulates all of the mutuıal information. In this way, the accuracy of the information is about 98.5%. The classification of the algorithm is compared with FDT method. It is found that the fuzzy tree method has superiority, It is similar to the fault tree method which is used for the detailed root cause analysis. The fuzzy decision tree shows all the relations between signals and the classification may be done more efficiently. [4]

2. Root Cause Analysis Necessity

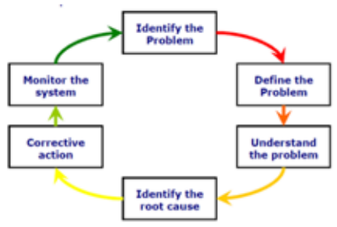
The root cause analysis starts with the problem definition phase; which supports the investigators to grasp and solve them. When it is decided to use root cause analysis methods. Problem definition is so crucial to determine convenient root cause analysis in purpose of being close more the right solution. In Figure 1, the short indication of a problem and potential causes are located. If the root causes of the problem are not analyzed properly, the problem may perpetually have the potential of



recurrency.

Figure 1. The Problem with Causes [9]

The cycle for the problem solving which is so familiar is indicated in Figure 2. Understanding the problem is the first step and in order to define the action, the root cause identification



is critical which is the key of the blockage.

Figure 2. Problem Solving Process [10]

2.1. The Root Cause Analysis In Aviation

The root cause analysis method is so common in the aviation sector which is cited fundamental regulations as follows. The preventive actions should be defined for the problems whose root cause is found out to not have recurrency. The corrective actions may be completed when the root causes are eliminated. There are also 18 pcs citations of root cause analysis in EASA Notice of Proposed Amendments (NPA) in NPA 2013-01 (B) 'Part-M and 13 pcs citation in NPA 2013-01 (C) 'Part-145; this proves the importance of the root cause analysis for the aviation. [11]

2.2. The Root Cause Analysis Methods

The five fundamental methods will be defined based on the severity of the faults. Common five root cause analysis methods are used in aviation.

2.2.1. Five - Why Analysis Method

The 5-Why method is firstly investigated by Sakichi Toyoda, by Toyota company in 1958, preferred as a first approach to close potential solution, it is generally used for the minor problems and performed the solution. It is realized by asking why to causes, and after 5 iterations alternative causes may be defined. This is a so practical method. In Figure 3, workable areas of why questions are asked consecutively [12].

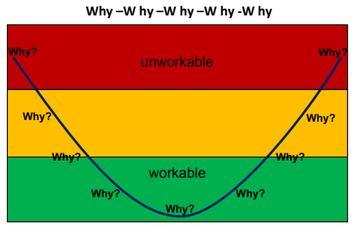


Figure 3. 5-Why Method Workable Areas [12]

2.2.2. Fishbone (Ishikawa) Analysis Method:

The fishbone analysis defines relations between cause and outputs with factor classifications. This method was firstly discovered by Prof. Kaoru Ishikawa in 1942. [12] The potential causes are classified as environment, person, material, machine, process, and others. All of the causes are filled out and the output is the problem. All of the causes are scored by the core team and priority is defined which may be supported by using the Pareto diagram. As a result of this effort, an action list is created to analyze the results. In Figure 4, the fundamental structure of this method is indicated.

Technique Example: Fishbone (Ishikawa)

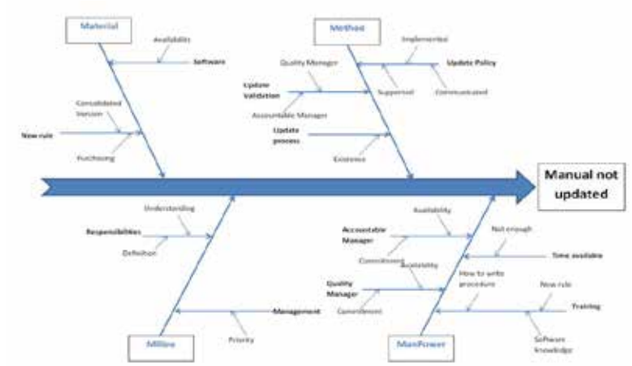


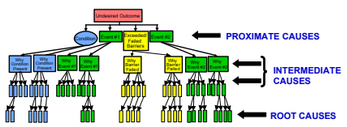
Figure 4. The Fishbone Root Cause Analysis Structure [12]

2.2.3. Fault Tree Analysis Methods

The fault tree is used to extend related potential causes for the different events and conditions. The events which cause the undesired outcomes are inquired as ''why'' and potential causes and the causes are classified as proximate cause, intermediate cause and the root cause [13]. In Figure 5, the Fault tree instance is shown which potential causes are evaluated with the related events and may be eliminated from the table.

Figure 5. Fault Tree Analysis Structure [13]

Root causes are systemic problems



or global factors located at the bottom of the tree. The contributing factors are sometimes left on the tree to show all factors that affected the event. Contributing factor means an event or condition that may have contributed to the probability of an outcome which isn't hoped but, if it was modified or disappeared, wouldn't by itself have impeded the probability. The fault tree analysis root cause method is preferred when there are several inputs, parameters, and events concerning conditions. [13] Consequently, this method identifies possible causes and different levels of occurrence.

2.2.4. Bow-Tie Method

The bow tie method is used commonly as a root cause analysis which defines the causes and consequences. The event is located in the middle of the causes and consequences. The causes are classified as basic and immediate causes. Basic causes are coming from personal and job factors; immediate factors are about acts and conditions. The causes and consequences are specialized by this method. Consequences are also classified as immediate and ultimate consequences. In Figure 6. the bow tie method is indicated as schema.

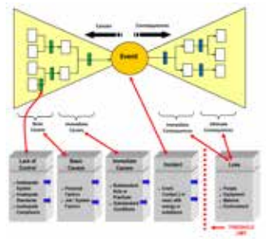


Figure 6. The Bow-Tie Analysis Method [14]

The bow tie method defines the risks and threats which present to taken preventive actions before the risk is realized as a proactive solution. These steps are used for the method of the bow tie as follows.

1. Definition of the dangers
2. Definition of non-desired conclusions
3. Definition of threats
4. Determine the outputs
5. Define preventive actions
6. Determine the factors of escalations.

The bow tie analysis method may be combined also with the Swiss Barrier model. Identifying the barriers is the most crucial to the bow tie method. It makes the create relations between all potential causes and risks. This is so beneficial to find out more deep outcomes of each part of safety and reliability in an organization. [14]

2.2.5. 8D Method

The 8D is also referred as Ford TOPS 8D, 8D, and Global 8D. This methodology is preferred for many industries particularly for the automotive sector. It is used like standardized process generally. It encourages to work together to solve problems with using 8 steps of the method to approach potential causes and effects. It is so efficient to define root causes and determine the permanent corrective actions. There are plenty of report to provide noncurrence of common problems with this method. The method consists of the process schema, cause and effect diagram, Pareto analysis and the other root cause analysis methods which are mentioned in this study. 8D is used to find the root cause and optimize all the duration to take long term actions. There are 8 pcs steps for the method. [15]

1. Notify the Awareness
2. Describe the Problem
3. Implement and Verify Short Term Corrective Actions
4. Define and Verify Root Cause Analysis
5. Verify Corrective Actions
6. Measuring of Effectiveness
7. Prevent Recurrence
8. Conclusion

Results and Discussions

The common root cause analysis methods which have been used for the aviation sector were researched and classified considering the criticality of the failures as an output. These methods are so crucial in the

purpose of sustaining the know-how and reflect the detections as lessons learned for new designs. Furthermore, the instances are supported by famous manufacturer aviation companies and related researchers.

When a nut design is considered as an aviation part, for instance, this part design shall be evaluated in terms of form, fit and function. The form refers to its construction and convenience for installation and serviceability.

The fit refers to dimensional features related to form and indicates the compatibility of the part on the assembly surface.

The function refers to its structure which is the main reason for the usage of it. For instance, the nut isn't used only for assembly of the shaft, it may also balance dynamic stress with keeping durability.

These fundamental terms are so crucial for the designation phase of aviation parts. These terms support to sustain Design FMEA during the development phase and it makes the detect root cause easier when any problem occurs with using an appropriate problem-solving process.

3. CONCLUSIONS

The commonly used root cause analysis methods that belong to aviation parts are consolidated in this investigation to classify them based on the criticality levels of the problems. Especially; aviation regulations and the studies of famous producers from the aviation were examined. (EASA, CAA, NASA, Boeing, Lockheed Martin, etc.) It is understood that the root cause analysis methods both support solving the problems properly with less time due to prevent recurrency and sustaining the know-how extension of the producers for every sector. This paper points out selecting the right root cause analysis methods against the criticality level of the problems is so crucial. Thereby, in the light of this review research, the methods are classified and indicated in Figure 7 as a result, It is indicated for the researchers. For the minor issues, the 5 Why method is preferred, but for the solutions of

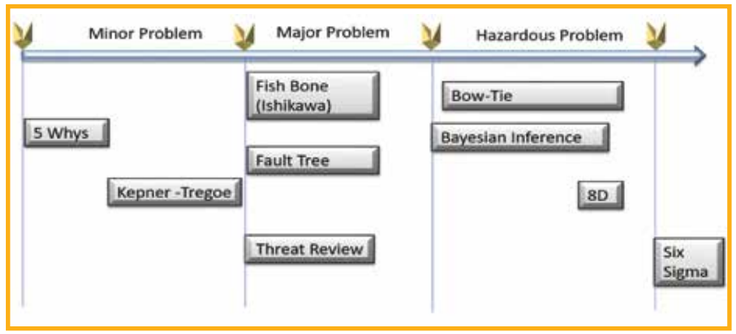


Figure 7. Root Cause Analysis Methods Offered to be Selected According to The Criticality of Problems

major problems, the Fishbone method is used, as well the fault tree is preferred when the preventive actions would be defined.

4. Nomenclature

FAA: Federal Aviation Administration

CAA: Civil Aviation Authority

NASA: National Aeronautics and Space Administration

EASA: European Aviation Safety Agency

NATO: North Atlantic Treaty Organization

ACT: Accident Causation Tree

SCW: Swiss Cheese Model

FMEA: Fault Mode and Effect Analysis

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[16] EASA Part Regulation; M.A.905(c)

FOREIGN OBJECT DAMAGE CERTIFICATION FOR TURBOSHAFT ENGINES

BY IBRAHIM ATACAN KILIC

Foreign Object Damage (FOD): *It is the physical damage of engine or engine main flow way due to entry of a foreign object inside the engine. Damages arising from foreign object adversely affect operational characteristics of engine, causing loss of performance, decreased operational stability or failure of engine.*

INTRODUCTION

Rotary wing aircrafts, i.e. Helicopter, may perform missions such as vertical take off and landing, hovering for a long time and search and rescue due to low operation speeds, fire-fighting, ambulance, etc. The fact that they have higher operational success in these areas compared to fixed wing aircrafts has helped to grow the mission profile of rotating wing aircrafts. One of the big factors in this situation belongs to turboshaft engines that power the rotating wing aircrafts. With auxiliary sub-systems that can be integrated into the turboshaft engine and materials with high foreign object damage tolerance used in the design, aircraft operations can be supported without compromising engine performance and power ratings.

Turboshaft engines are a type of gas turbine engine optimized to produce shaft power rather than thrust, and have been used as the main power supply in rotating wing aircrafts since 1950s. Systems used in turboshaft engines such as inlet particle separator, air filters, etc. can remove foreign objects that may enter the engine from the engine without interfering with the main flow line. With the anti-icing system, ice accumulation at the engine inlet can be prevented, and designs with high damage tolerance can be performed with the increase of alternative materials.

With advance wing designs, development in manufacturing technologies and ability of engines to reach high speeds have ensured that light and smaller turboshaft engines with fuel efficiency can be manufactured. However, while the dimensions of foreign object that can cause damage remain fixed, their component productivity raised with the increase of their design and manufacturing capabilities, and the number of critical components in the main flow way decreased, and their dimensions have been decreased.

Foreign object damage in gas turbine engines is widely occur in the compressor section. Foreign object damage can be divide into two categories, the effect of which can be tolerated or cannot be tolerated by engine.

FODs whose effect on the engine can be tolerated by the engine are the type of FOD that cannot be detected during operation and can be observed with maintenance and inspection. These FODs may cause distortion in the air in main flow profile of the engine and disrupt the flow, and may create minor effect or temporary sudden performance loss on the performance of the engine. Tolerating the effect of such FODs can increase the fuel consumption, which may result in reduced maintenance period of the engine or require unplanned maintenance and repair.

FODs, whose effect cannot be tolerated by engine, prevent the engine from stable operation, causes excedence of the engine limits which are specified in the engine manual. Due to the physical damage occurring in mechanical or structural components of the engine, the engine may need to be shut down. In this article, foreign objects that enter the engine during the aircraft operation will be evaluated, and requirements included in the Certification Specifications for Engines (CS-E), which is established by the European Union Aviation Safety Agency (EASA) for FOD hazard in civil turboshaft engine projects, will be mentioned, and information with regard to verification activities and acceptance criteria for damage tolerance designs applied in engine design processes will be provided.

POTENTIAL FOREIGN OBJECT DAMAGE REASONS FOR TURBOSHAFT ENGINES

Reasons that may pose a FOD hazard for turboshaft engines can be examined under 3 categories: operational environment, placement of the engine on the aircraft, and maintenance.

Operational Environment:

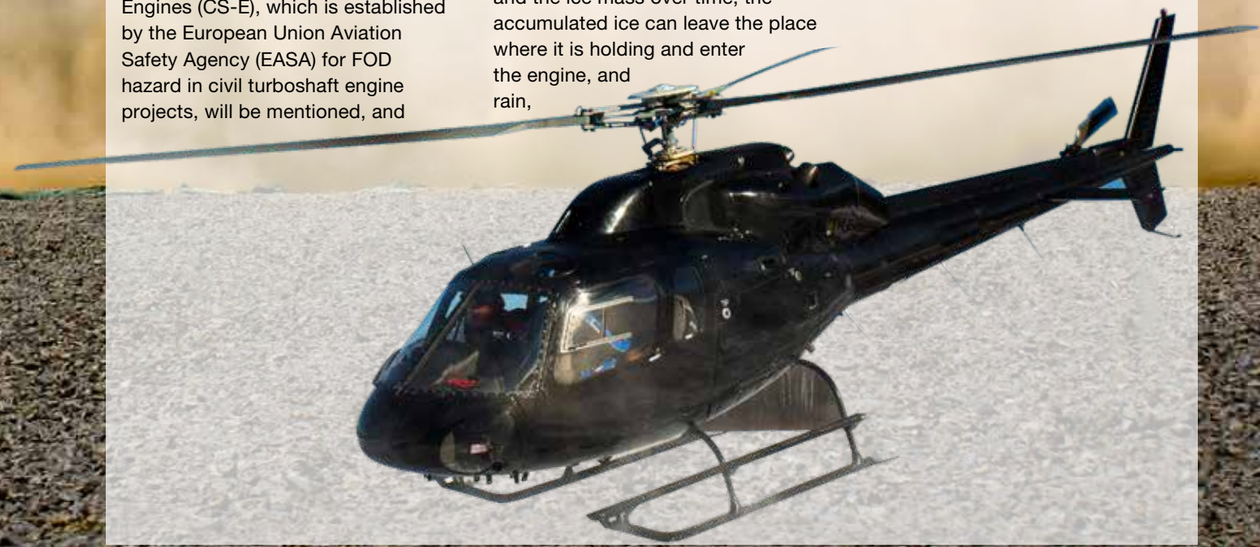
Helicopter performs a significant part of its operation by flying and hovering at ground level. Meanwhile, objects such as gravel, sand, dust, grass, etc. may be pulled into the engine from the ground with the aerodynamic effect of the helicopter's propeller. In addition, it can operate in environments such as deserts, where high concentrations of dust and sand in the air are in question. Also, in cold weather conditions, ice accumulation may occur in certain parts of the aircraft or engine inlet. With the decrease of surface tension between the surface and the ice mass over time, the accumulated ice can leave the place where it is holding and enter the engine, and rain, hail and snow due to weather events, bird strike encountered during operation or parts of bird may be pulled into the engine.

Installation Condition of The Engine to Aircraft:

Engine inlet line and interface fasteners pose a potential FOD hazard. Due to reasons such as high vibrations as a result of main rotor of helicopter, incomplete assembly, etc., fasteners between engine-aircraft can be loosen and parts that are broken or dislodged from the inlet line may enter the engine. Also, as a result of freezing water on places where water may accumulate at the inlet of engine, mass of ice may enter the engine.

Maintenance:

During maintenance, fasteners (nut, bolt, etc.) hand tools (screwdriver, wrench, maintenance mirror, etc.) cleaning materials (fabric, sponge, etc.) of the persons responsible for maintenance of engine may be forgotten in the environment where maintenance is performed. Also, other goods belonging to the maintenance personnel, objects that may exist



in the maintenance environment potentially pose a FOD risk.

In order to prevent foreign object damage and therefore the engine can maintain its operation safely with the aircraft, necessary design solutions should be produced by identifying potential foreign objects that may enter the engine and concentrations of foreign object to be exposed during the engine operation, and verification activities should be carried out for proof of the functioning of these solutions. Foreign objects in CS-E are divided into those affecting a single engine and affecting multiple engine. Effects of foreign object damage on the engine are evaluated in the following paragraphs according to CS-E, and acceptance conditions are specified. In addition, verification activities for foreign object damage and CS-E objects that may be referenced are mentioned.

1- Acceptance Criteria for Foreign Object Affecting a Single Engine

Creating Engine Impact with a single engine effect, whose impact cannot be tolerated by the engine. The hazards for what may be considered FOD induced Engine Effect for a turboshaft engine are given below.

- With the strike effect of foreign objects, distortion of structural integrity of engine rotating parts,e.g. discs, and release of high-energy parts out of the engine.
- Concentration of toxic products in the Engine bleed air for the cabin sufficient to incapacitate crew or passengers.
- Fire that cannot be uncontrolled fire due to FOD effects.
- Failure of the Engine mount system leading to inadvertent Engine separation caused by distortion of the load balance.
- Failure to stop the engine by emergency or normal procedures.

2-Acceptance Criteria for Foreign Object Affecting Multiple Engine

Foreign object that may effect multiple engines can cause effects that can be or cannot be tolerated by engine. Even though acceptable performance loss and damage levels are defined according to foreign object type in the relevant CS-E paragraphs, performance and strength criteria the engine must provide after the FOD test can be specified under three criteria defined below. As a result of the data obtained from the tests carried out with the engine and the relevant sub-systems, proofs should be established these criteria have been met.

- Sudden or permanent loss of performance, sudden performance loss more than 10% due to rain, hail and ice ingestion, permanent performance loss by over 5% for ice mass and over 3% for hail ingestion test.
- Distortion in operating features of the engine, engine maintenance requirement due to mechanical damage, inability to continue the operation until the next scheduled maintenance, etc.
- Due to unstable operation of the engine, exceeding any operating limit such as speed, temperature, torque, etc.

Detailed information on foreign object damage is given in Table-1. Relevant CS-E specification for the details of acceptance criteria and test profiles can be examined.

Source of FOD	Foreign Object	Number of Affected Engine	CS-E Object	Verification Method
Operational Environment	Pebble	Multiple engines	CS-E 540	Foreign Object Testing - Motor and related sub-systems (Inlet particle separator)
	Sand-dust	Multiple engines	CS-E 540	Sand and dust testing - Engine and related sub-systems (Inlet particle separator)
	Ice accumulation, snow	Multiple engines	CS-E 780	Engine and related sub-system tests according to CS-E 780
	Rain and hail	Multiple engines	CS-E 790	Engine test according to CS-E 790
	Single large bird	Single engine	CS-E 800	Single Large Bird Test according to CS-E 800 - engine test
	Medium and small-sized bird	Multiple engines	CS-E 800	Medium and small sized bird test according to CS-E 800 - engine test
Engine Aircraft layout	Bolts, nuts, fasteners	Single engine	CS-E 540	Foreign Object Testing - Motor and related sub-systems (Inlet particle separator)
	Ice accumulation, snow	Multiple engines	CS-E 780	Engine and related sub-system tests according to CS-E 780
Maintenance	Bolts, nuts, rivets, fabrics, screwdrivers, etc.	Single engine	CS-E 540	Foreign Object Testing - Motor and related sub-systems (Inlet particle separator)

Table 1.

Alternative verification methods that can be used for turboshaft engines can be listed as follows.

- Compliance with the requirements with regard to medium or small-sized bird strike for engines that will be used double engine rotating wing aircrafts may not be mandatory depending on the inlet of the engine on the aircraft. These tests may not be performed when compared to damages caused large bird strike or other foreign objects.
- If the effects caused by blade failure are more severe than single large bird strike, blade rupture testing can be used as evidence and single large bird test may not be carried out.
- If the effects of single large strike are more severe than the effects to be caused by entering foreign objects such as cleaning fabrics, bolts, nuts, rivets, etc. into the engine, verifications for these objects can be carried out with single bird strike test. Depending on the aircraft engine inlet, all these tests for turboshaft engines can be performed with a blade failure test performed under CS-E 810.
- Damage from foreign object adversely affect operational characteristics of engine, causing loss of performance, decreased operational stability or failure of engine. Using inlet particle seperator, anti-icing systems and material with high damage strength in engine design minimizes foreign object damage and increases the engine's operational capability. Safe operation of the engine can be guaranteed by using CS-E published by EASA for capability demonstration with FOD in civil projects. For each FOD type, the design can be directed and design verification activities can be carried out by referring to the paragraphs of the relevant CS-E, and the airworthiness of the engine can be guaranteed.

WHO IS IBRAHIM ATACAN KILIC

He was born in Ankara in 1991. He graduated from Istanbul Technical University, Department of Aerospace Engineering in 2016. He has been continuing his post graduate education in Gebze Technical University in the Applied Propulsion System Design Engineering for Aerospace Technologies department since 2020. He has been working as Engineer at Airworthiness and Certification Management since 2018.

NEW APPOINTMENTS IN OUR COMPANY BETWEEN JUNE 30, 2020 - DECEMBER 31, 2020

Burak Balci
was appointed as Compressor Manager at Turboshaft Engines Directorate on September 1, 2020.

Selim Emre Ulucan
was appointed as High Pressure Turbine Manager at Turboshaft Engines Directorate on September 1, 2020.

Huseyin Bayraktar
was appointed as Material Planning and Inventory Manager at Manufacturing Directorate on September 1, 2020.

Gursel Boz
was appointed as Programs Manager at Programs Directorate on September 1, 2020.

Erdem Kuscu
was appointed as Supplier Development Manager at Finance and Supplier Directorate on September 1, 2020.

Kadir Aktas
was appointed as Technical Leader at Electric, Electronics, Control & Embedded Systems Management on August 1, 2020.

Ali Canpolat
was appointed as Technical Leader at Electric, Electronics, Control & Embedded Systems Management on August 1, 2020.

Ali Gokhan Genc
was appointed as Senior Technical Leader at Operations Management on August 1, 2020.

Kerem Ozdemir
was appointed as Senior Technical Leader at Information Technologies Management on October 1, 2020.

Ugur Akin
was appointed as Technical Leader at Compressor Management on October 1, 2020.

Fatih Oztoprak
was appointed as Technical Leader at Operations Management on November 1, 2020.

Hakan Dinc
was appointed as Shop Supervisor at Testing Management on November 1, 2020.

Muhittin Arslan
was appointed as Shop Supervisor at Testing Management on November 1, 2020.

Guvenc Danaci
was appointed as Technical Leader at AIT & MRO Planning and Operations Manager on November 1, 2020.

Tolga Asa
was appointed as Technical Leader at Turbojet and Turbofan Engines Management on November 1, 2020.

Mehmet Can Bicen
was appointed as Technical Leader at Turbojet and Turbofan Engines Management on November 1, 2020.

Hulya Tatas
was appointed as Senior Technical Leader at Turboshaft System Design & Integration Management on November 1, 2020.

Efecan Kutlu
was appointed as Technical Leader as Quality Management on November 1, 2020.

Muzaffer Karagoz
was apointed as Technical Leader at Supplier Development Management November 1, 2020.

Emrah Gultas
was appointed as Senior Technical Leader at Operations Management on December 1, 2020.

Kerim Kahraman
was appointed as Senior Technical Leader at Performance and Functionality Leadership on Decembe 1, 2020.

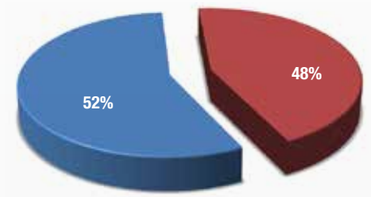
Alican Kutmaral
was appointed as Technical Leader at Compressor Management on December 1, 2020.

Ahmed Hayreddin Celikkaya
was appointed as Affiliates Coordinator at Finance & Supplier Directorate on December 24, 2020.

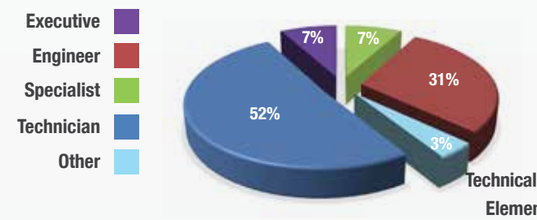
STATISTICS ON TEI'S EMPLOYEES

In respect of our 2,587 employees as of December 31, 2020;

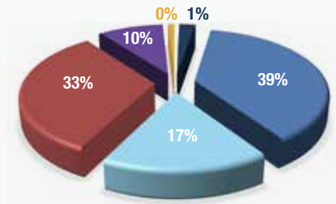
Breakdown of White-Collar and Blue-Collar Employees



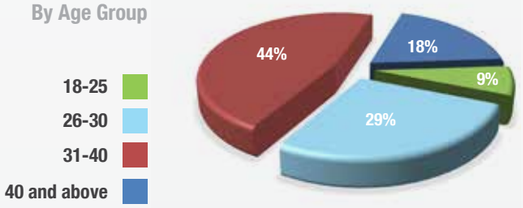
By Title Group



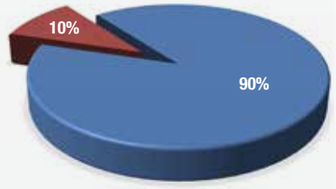
By Educational Status



By Age Group



By Gender



Visits to our company from various institutions continued in the second half of 2020.

06.08.2020

Visit by Erol Ayyildiz, Governor of Eskisehir

07.10.2020

Visit by Hasan Buyukdede and Ali Cetin Donmez Ph.D, Deputy Ministers of The Ministry of Industry and Technology

17.12.2020

Visit by Seref Malkoc, Chief Ombudsman of the Republic of Turkey, and Accompanying Delegation

21.07.2020

Visit by Prof. Mehmet Kul, Rector of Sivas University of Science and Technology

28.07.2020

Visit by Prof. Rafet Bozdogan, Chairman of the Board of Turkish Aerospace Industries Inc., and Lecturers of Yalova University

20.10.2020

Visit by Ahmet Nuri Oguz, Manager of Eskisehir City Directorate Population Registry and Citizenship

24.12.2020

Visit by Brigadier Yusuf Erge, Eskisehir Air Control Group Commander

15.10.2020

Visit by Ortadogu Rulman Industry Delegation

09.10.2020

Visit by Turkish Aerospace Industries Inc. Corporate Marketing and Communications Leadership Delegation

TEI
TUSAŞ MOTOR SANAYİİ A.Ş.
TUSAŞ ENGINE INDUSTRIES, INC.

TURKEY'S
LEADING ENGINE
COMPANY

TEKNOFEST 2020

World’s largest aviation festival TEKNOFEST aiming to increase awareness of Turkey’s transformation into a technology-producing society and to increase interest in technology was organized for the third time in 2020. The organization was on September 24-27 in Gaziantep, the capital of gastronomy and one of the first settlements of Anatolia at the intersection of Mesopotamia and the Mediterranean. TEI exhibited the mock-up and additive manufacturing parts TEI-TS1400, Turkey’s first national turboshaft engine. TEI was also the main organizer of the Jet Engine Design Competition at the festival.

JET ENGINE DESIGN COMPETITION

TEI's Jet Engine Design Competition aimed to design the cooling of the first-grade fixed winglet in the gas generator turbine module of a turboshaft engine. Thanks to this competition, it is targeted to contribute positively to skillful worker's shortage in Turkey and continuity in such a critical subject.

A total of 146 teams consisting of undergraduate and postgraduate students applied to the turbine cooling design competition, organized as a part of the Jet engine design competition. The preliminary design report qualified 31 teams to the critical design phase. Competitors attended a 16-hour basic gas turbine engine and turbine cooling training by TEI engineers online in May. The designs of the 6 finalist teams were subjected respectively to a cold flow test, where the use of cooling air is aimed to be measured, and a thermal paint test, where metal temperatures of the winglets are compared. Then, the team's ranking was determined. On the 3rd day of Teknofest, the competition award ceremony took place with the presence of His Excellency Mr. President Recep Tayyip Erdogan.

TEKNOFEST 2020 Technical Team

Erinc Erdem, Ph.D - Principal Engineer
Sinan Sal, Ph.D - Principal Engineer
Mustafa Cem Sertcakan - Lead Engineer / High Pressure Turbine
Mercan Mut - Lead Engineer / High Pressure Turbine
Tugce Karatas - Lead Engineer / High Pressure Turbine

SAHA EXPO FAIR

TEI participated with a stand-in Turkey's first virtual fair organized by SAHA Istanbul Defence, Aviation, Aerospace, and Industry Cluster online due to pandemics. TEI exhibited TEI-PD170 turbodiesel aviation engine, TEI-TS1400 turboshaft engine, TEI-PG50 2-stroke gasoline aviation engine, and TEI-TJ300 turbojet engine in the fair opening on November 9 and visited by the visitors for the next 5 months.

ASME THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS 2020 TURBO EXPO

Erinc Erdem, Ph.D. Principal Engineer at TEI was co-chair of the "12-01 Air Systems and Seal Design 1" session at ASME The American Society of Mechanical Engineers 2020 TURBO EXPO held.

SOCIAL RESPONSIBILITY

TEI, UNDER THE NATIONAL TECHNOLOGY MOVE, DONATED 1,000 TABLETS

TEI donated 1,000 tablets under the National Technology Move program launched to contribute to the education of students who do not have the opportunity to access distance education.

TEI ALPARSLAN PRIMARY SCHOOL RENOVATED

TEI renovated TEI Alparslan Primary School to provide a better and more productive educational environment. After repair work, the physical conditions of the school were improved.

TEI STAMP IN ESTABLISHMENT OF DOMESTIC AND NATIONAL R&D ENGINE TEST CELL

BY AHMET BASDOGAN

The first engine tests were successfully performed in 2020 in engine test cells, whose manufacture, installation and test processes are completed, in order to provide input to the development processes of TEI-TJ300 engine that is developed by TEI under the Medium Range Anti-Ship Missile Engine project.

The phenomenon of “test” which yacked up in our language, has the meaning coordinate indicating different points in each of tens of different channels where it is used. When evaluated within the scope of engineering activities conducted in R&D processes, even though it can be defined in different ways, it will be appropriate to use the expression of “simulation of the real life” for test activities. When we focus specific to aviation engines, engine tests are carried out to implement the condition to be faced by engine at real life namely at the platform where it will be used and to evaluate and record its behaviour / strength and functionality under these conditions. Accordingly, scraping the expression of “Aviation history is written with blood” is only possible with engine tests that can provide ideal conditioning and a complete record of behaviour.

Test activities are very important for TEI, which develops Turkey’s indigenous engines, in order to conduct design processes in a healthy, reliable and productive manner. At this point, behaviours of the indigenous engines developed by TEI on the platforms, where they will be used, will be simulated through engine test cells and their performance is recorded.

As with any installed infrastructure, manufacturing and installation processes in test systems can be generally classified either through sub-contractors or as domestic installation. In particular, given the fact that there are almost no domestic alternatives in the manufacturing and installation of engine test systems, advantages that can be summarized below make the domestic installation alternative come to the forefront:

- Ensuring to have know-how knowledge at the point of installation of systems,
- Development of indigenous test and control software, application capability acquisition,
- Flexibility of test systems with regard to hardware and software,

- Realization of modifications that may be needed in a manner desired by the team that has established the test system,
- The possibility of creating a setup that can reach quickly in the maintenance and repair processes.

In line with the facts specified in this article, supports and vision of SSB (Presidency of Defense Industry), and as a result of combination of TEI mission and vision; details on some of engine test cells, whose domestic and national manufacture, installation, commissioning and test periods have been carried out within TEI, are provided.

TEI-TJ300 TURBOJET ENGINE TEST CELLS

R&D Test cells for Turbojet engines, which is one of the most important variant of gas turbine engines, composed of air inlet and exit management, thrust measurement which is the most critical input for engine performance, test stand, control and data acquisition infrastructure and engine start systems.

The first engine tests were successfully performed in 2020 in engine test cells, whose manufacture, installation and test processes are completed, in order to provide input to the development processes of TEI-TJ300 engine that is developed by TEI under the Medium Range Anti-Ship Missile Engine project.

Figure 1. TEI-TJ300 Engine Start-Up Memory

Figure 2. TEI-TJ300 Start-Up Memory with the Minister of Industry and Technology

TEI-TJ300 Turbojet engine test cell, which is designed and manufactured entirely by TEI engineers, has the following capabilities:

- Indigenous and flexible control / software infrastructure,
- Capability to test turbojet engines up to 2.000 Newton thrust,
- Measurement capability for a total of 104 parameters including 32 channel temperature, 64 channel pressure and 8 channel vibration,
- Ability to operate an engine without an engine control unit through the cell control system,

- Ability to operate engines with windmilling, air start and e-start,
- Two separate fuel supply system of 10 and 60 bar,
- Fuel conditioning system from -40 to +80 °C,
- Lubrication system, which can lubricate the front and rear bearings at flow levels and can be conditioned in terms of temperature,
- Air measurement and control capability with bleed ports,
- High level sound insulation capability obtained by using fully acoustic coating materials.

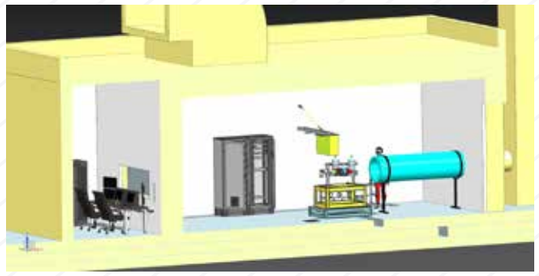


Figure 3. TEI-TJ300 Engine Cell Design

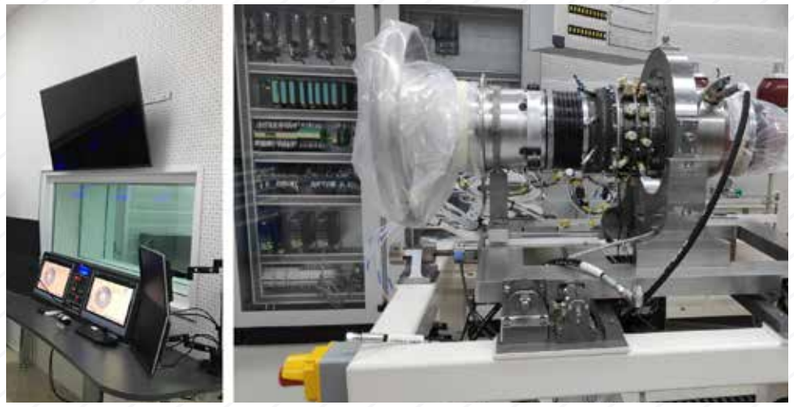


Figure 4. TEI-TJ300 Cell

As a result of intensive test processes as of the first quarter of 2021, the TEI-TJ300 engine broke the world record in its own right, reached 48.500-rpm corrected speed and 1.342 N corrected thrust level.

Figure 5. TEI-TJ300 Engine Test

TEI-TS1400 TURBOSHAFT ENGINE TEST CELL

Turboshaft engines produce shaft power instead of thrust which can be stated as the main difference between turbojet engines. Due to this difference turboshaft engine test cells include dynamometer which is integrated to the power turbine shaft of turboshaft engine for both real life simulation and the measurement of torque / power. With the inertia simulation configured in turboshaft engine test cells, simulation of the resistance to be applied by transmission organs and propeller of the platform where the engine shall be integrated can be provided. Also, as in turbojet engine test cells, setup and integration of start-up and auxiliary systems according to engine maturity levels plays an important role in the manufacturing processes of turboshaft engine test cells.

The engine test cell designed and manufactured by TEI engineers in order to execute tests of TEI-TS1400 turboshaft engine that is developed by TEI under the cover of the T625 GOKBEY General Purpose Helicopter and Turboshaft Engine was commissioned and the testing processes were started as of the last quarter of 2020.

Engine test hush house which is designed and manufactured in order to execute TEI-TS1400 Turboshaft Engine tests, which is developed by TEI, was commissioned as of last quarter of 2020, and test processes were initiated.

The capabilities of the TEI-TS1400 engine test cell, where nearly 100 tests were carried out as of the first quarter of 2021, can be summarized as follows:

- **Indigenous and flexible control/software infrastructure,**
- **Capability to test turboshaft engines up to 2500 shp level (30,000 rpm, 895 Nm),**
- **Ability to operate engines with air start and e-starter,**
- **Ability to operate an engine without an engine control unit through the cell control system,**
- **A total of 368 channels of static data collection capacity, including 128 dynamic data collection capacity, 160 temperature, 208 pressure,**
- **Fuel supply system capable of supplying up to 200 g/s and 345 kPag,**
- **Supply up to 25 lt/min, capable of suction up to 20 lt/min level; lubrication supply system that can be conditioned to 130 C level.**

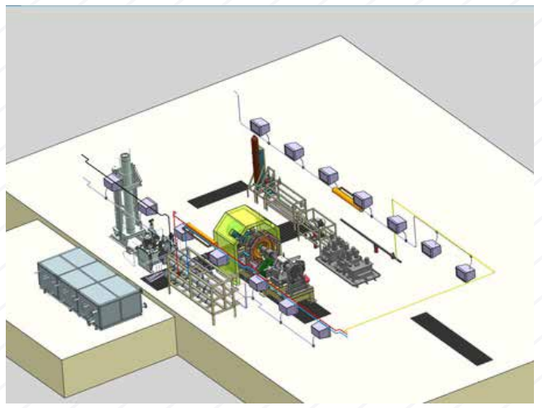


Figure 6. TEI-TS1400 Engine Test Cell Design

Figure 7. TEI-TS1400 Test

CONCLUSION

The most obvious evaluation that must be made with regard to domestic, national and TEI signed R&D engine test cells, about which only two examples and summarized capabilities are provided above, are test requirements, possibility of rapid and efficient modification within the framework of engine needs. This rapid response capability has provided positive contribution to engine development processes at undeniable level. At this point, we can say as the final evaluation that engine test cells whose domesticity, diversity and capability has been increasing will increasingly support engine development and design revision verification processes.

The fact that R&D test cells and component test systems, which are under installation, provide healthy and sustainable design inputs to TEI engine development processes and then reach to the position of offering service to different companies developing engine within the country, will ensure the sustainable growth of TEI in the aviation engines industry and will establish the milestones of the road leading to world-ranking leadership.

WHO IS AHMET BASDOGAN?

He was born in 1984 in Adana. He graduated from Sabanci University, Mechatronics Engineering in 2008. He completed his master's degree in Sakarya University, Engineering Management department in 2017. Since 2017, he has been working as Technical Leader at Test Management.

Stating that he started his interest in wood by growing up in a forest village, Yusuf Gunes, starting with this hobby at first with plastic hobby kits; then he shaped inert wooden pieces. Currently, he voluntarily participates in classroom activities and gives information when requested.

HAVE A HOBBY WOOD

When one said "Do something for yourself in life", one of the first ideas that comes to mind is having a hobby.

From ancient times until now, people have used wood. They used the tree for many needs such as hunting, shelter, creating a living space. Today, we see traces of wood everywhere. When my grandparents emigrated, they preferred forest for their first settlement. Right now, our village is a forest village at an altitude of 1,300. That must be reason for the relation between me and wood. My grandfather did the carpentry works of our village, our existing house in our village is made of wood and has been safe and sound for many years. Trees are very important for our lives, and their benefits are countless.

SO, WHAT IS HOBBY?

It is overall skill-based and amusing activities, which do not have to be carried out, falling under one's profession or different profession type and which are generally made to spent leisure times.

Hobbies have more functions than spending leisure times of people. They increases the visual and verbal abilities of the person, decision-making and communication skills, and ability to work with the team. They also makes it easy to communicate and facilitates socialization. That is to say, when we share our works on social media, it will become easier for us to reach different persons and make a circle of friends with likes and comments.

My first hobby began with plastic ready-made kits. Then, "Why don't I do it myself instead of using the ready-made kits?", I said myself. I started shaping the scrap boards I found with hand tools, as the products appeared, I started to spend more time on my hobby. Then I established my own workshop. When you inhale the smell of wood, and beautiful products are manufactured, your love begins for the wood...

Shaping a recycled wood, increasing its value, receiving beautiful comments from others allow you to move forward for this hobby and infatuate you with this hobby. I spend my time in my workshop with various tools and machines, shaping toys that are normally made of plastic today from wood and making decoration products.

The best point of my occupation is introducing wood to children and organizing event with them, inculcating the smell and texture of wood into them.

When we make effort for a hobby we have, we can unwittingly explore new ways and discover our unfamiliar abilities.

According to pedagogical research, the effect of hobbies on an adult life is the same as the effect of toys on a child. As adults, we also should develop a hobby and create small workshops where we can relieve our daily stress.

WHO IS YUSUF GUNES?

Born in Eskisehir in 1980, Yusuf Gunes has been working as Chief Technician at Quality Management since 2004.

A SEASIDE TOWN

FOÇA

BY TUGAY ASKIN ATES

Tugay Askin Ates explained Foca, one of the most beautiful holiday destinations in the Aegean with its rich history, bays work exploring and lush nature, for TEI readers.

The Aegean is a region that contains many beauties of our country and where everyone can find something from themselves with its nature, sea, warm climate and unifying people. When we think of the Aegean, coastal towns are the first thing that comes to mind. Foca, one of the districts of Izmir, is a place where everyone feels peaceful and happy with its streets decorated with stone houses, fishing boats, colourful harbour offering a visual feast and sunset. And since I'm in the immediate vicinity of the city where I grew up, it means something different to me.

Foca stands out for its long history as well as its blue flag sea and bays. When it emerged as an Ion city in Archaic Age, it was named Phokaia because of seals living in the neighbouring seas. This name has survived to the present day as Foca. Because it is a port city, it has hosted many cultures and developed very quickly as it was also a maritime trade center. After the rule of the Ions, Persians, Alexander the Great and finally Genoese, it remained a Turkish port city until today thanks to Chaka Bey, who is one of the most important names of our maritime history as he created the first Turkish navy.

If you're a little lucky, you might have the opportunity to see the sea seals very closely here.

When you walk from the sea-smelling causey streets of Foca, which has a rich history and hosted many civilizations, to Beskapilar Castle, which was built at the center of the city in the 11th century, you can feel like you are in an open-air museum. You can go in and see inside the castle, which consists of five gates and was used as the entrance into the city in the ancient times, and can watch the unique sunset here or from Phrygia Hill. You can also buy souvenirs, which are essential for every holiday resort, from the stands set up next to the castle in the evening. By walking from Beskapi Castle to the old port, you can watch the islands and spectacular vies of the sea among the sea and fishing boats.

One of the first thing that comes to mind when we think of the Aegean is its narrow, long and colourful streets. There are quite a lot of such streets in Foca, which remind of photography studios. Walking through these streets where old stone houses are lined up is quite enjoyable and almost all streets lead to the old port. The old port is quite lively and the center of the city. You can taste Foca's mastic ice cream thanks to the ice cream makers located here.

You cannot mention about Foca without talking about its intense blue sea. You can join one-day boat tours from the old port and visit the most beautiful bays of the Aegean and have an extraordinary time. These boats depart every morning at 10:30 and have a very rich sightseeing route. Kosova Beach and Pigeon Island are just two of sights on this route. Sazlica bay with blue flag, which is one of the bays accessible by road and which I prefer due to the possibility of camping, is a nice alternative for large groups of people.

Finally, visiting Siren Cliffs, one of the musts of Foca, is at the top of the to-do list for everyone who comes here. It is also very easy to reach it by sightseeing boats located in the port area. Siren Cliffs, which resemble Fairy Chimneys in Cappadocia and which Homer mentioned in his epics, have a very interesting story. According to the legend, sirens, with their supernatural music they make, influence the sailors passing by, preventing them from leaving here. No wonder, that's the mythology side of it. Siren Cliffs are also home to many marine creatures. If you are a little lucky, you can have the opportunity to see the sea seals very closely here and leave with good memories.

Foca was a nice rest and sightseeing alternative for us after the density and noise of crowded cities. With its mosaic consisting of sea, nature and history, this small seaside is just one of the beauties worth discovering in all four sides of our country. Leaving Foca with happiness and peace, where we came with a sense of curiosity and excitement, was the most enjoyable part of this trip for us.

WHO IS TUGAY ASKIN ATES?

Born in Izmir in 1994, Tugay Askin Ates graduated from Dokuz Eylul University Mechanical Engineering and Industrial Engineering departments in 2017. Since 2019, he has been working as Engineer at Turboshaft Program Management.

our employees WHO RETIRED

BETWEEN
1 JULY - 31 DECEMBER, 2020

- **AYCA OZERDEM** retired as Senior Specialist on July 1, 2020,
- **ERDAR SIPAHIOGLU** retired as Senior Engineer on July 24, 2020,
- **HAMDI EGILMEZLER** retired as Expert Technician on August 5, 2020,
- **KADIR EROL** retired as Chief Technician on September 11, 2020,
- **NURETTIN KARAMIK** retired as Shop Supervisor on October 30, 2020,
- **SEYFI KESTEL** retired as Chief Technician on December 26, 2020.

We wish them all the best in their lives after retirement

35 YEARS IN THE SKY

With its 35 years of experience, TEI, the leader in Turkish aviation engines, has been serving more than 50% of the global civil aviation industry.

TEI

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RECOMMENDATIONS TO BE EFFICIENT AND TO MAINTAIN MENTAL HEALTH WHILE WORKING FROM HOME

Working from home seems to many persons like a very good and relaxing opportunity to use the time spent on the road with family, for rest and personal interests. I thought it would be appropriate to share the results of applications with regard to this topic, which is on the agenda to be put into practice in many workplaces due to Covid-19, and what has been learned from the researches carried out.

Prof. Acar Baltas / Psychologist

The classic cliché of crisis periods is that “every crisis also contains an opportunity”. Institutions that will not even think of working from home order for its approach and corporate culture are trying to adapt to this system due to recent developments. This is an opportunity to reveal the creative potential within employees. Employees and managers, especially IT and HR departments, are in the process of an exam for adapting themselves to change and preparing for the future. This can also be considered as a test of corporate and managerial agility, which has been the fashion concept.

Being at home and focusing on work is a double-edged sword. This applies to both institutions and employees. The difficulty for institutions is due to the difficulty of measuring the actual productivity of the employee in many business areas and companies. Therefore, it is assumed that if employees are “under the spotlight and at hand”, they are doing their job. Especially in companies where the founding father’s methods apply, leaving the workplace before the boss is considered to be underestimating the work and is taken a dim view.

On the other hand, the situation is not easy for the employee. In societies consisting of individuals with weak self-discipline and accustomed to being governed by an external authority and having an external control focus, it is not easy for these individuals to perform their duties with seriousness within the scope of the business environment with their own will. For example, catching the image of accumulated pile of laundry at home and getting rid of this load may be a reason for some persons to do the work later whereas watching mini series on Netflix is a reason for some person to postpone this work. Such impulsive reasons may be more attractive than the work that the boss or manager imposes on the person. It’s relaxing to think as “After all, I have time to do what I’m responsible for”. However, focusing on the job and completing the task requires special effort and a systematic approach.

Research carried out on working from home displays that some principles that must be followed for the work order increase productivity.

For employees:

1. To be ready: Set the alarm, wake up at the time you set, do not neglect your personal care, have a good breakfast, wear a proper outfit dress and sit upright.
2. To create a working space: Prepare a place that you will only use for work during the working period. Definitely avoid using this place for activities other than work such as eating, socializing, watching TV, etc. Don’t even think about using a chair or a bed for work. If there are others in the house, set up an order with your door closed, free from disturbing noises. In England, for example, some families with young children and childminder I knew pretended to leave home during working hours and worked behind closed doors.

3. To make friends: People are social creatures and are tired of loneliness at various levels, depending on their personality traits. Dr. Thuv-vy Nguyen from Durham University says that although the sounds, unnecessary conversations and especially chatterers in the work place reduce activity, friend can also help improve productivity, for this reason choosing a friend to exchange ideas while working from home will be benefical.
4. To make plan and program: Making a daily plan is one of the important conditions for improving productivity for all type of works. Daily programs are influenced by others. But those who work from home need a structured plan more than ever. Dr. Nguyen stated that a structured program based on a daily timeline is the most basic element for those who work from home, especially those who are alone. Such a program should include a short walk outside, playing with children, short socialization with those at home, or a few rest breaks to be used to reply to private e-mails. Rest breaks should never be used to watch movies / videos or for browsing social media.
5. To diversify communication: Working from home is not just focusing on e-mails on the screen. For this purpose, it is possible to create similar lives as in the office environment using different digital tools. For example, using applications that allow face to face interviews can increase the efficiency of interactions through video conferences.

Issues to be considered in communication over the screen;

- If on-screen communications involve more than one person, appointing an administrator among them would be appropriate. Thus, the sounds do not mix, making it easier to listen and watch each other.
- The speaker in front of the screen needs to pay attention to the light behind him / her. Such light will cause the face to remain in the dark, making it difficult for others to watch.
- The important element of face to face communication is eye contact. The speaker naturally tends to look at the screen, however the eye contact effect is achieved by looking at the camera.

For directors:

1. To held regular meetings: Regular morning meetings are an application that must be implemented by the institutions that switching from home working model. In team meetings that do not exceed 15 minutes at a fixed time in the morning, employees explain their daily schedule and present the progress they have taken in the targets they set the day before. Some institutions add another meeting in the evening and prefer to collectively go over daily targets. Therefore, it would be possible for the directors to keep in touch with employees as much as possible, inform employees and make them feel that they are not alone, especially in situations such as the current Covid-19 pandemic.
2. To create team bond: Prithwiraj Choudhury from Harvard Business School, in his research where he examined the telecommuting, proposes the events held at geographically different locations are methods enhancing friendship. For example, celebrating birthdays of US team members via video conference and having each member send a personalized message to the person celebrating his / her birthday strengthen the team bond.

CONCLUSION

Working from home appears very relaxing, increasing productivity and a comfortable application at first especially it will avoid the loss of time and energy in traffic in a big city, however, it is not a convenient method for many people. Such a working order is stressful for everyone to a certain extent, depending on personality traits. Adapting to this situation requires special preparation and discipline for both institutions and employees. However, reaching the rewards at the end will be possible first and foremost by putting aside concerns and having mental hygiene.

OUR CARDIOVASCULAR HEALTH

Muharrem SENEL, M.D.
Cardiovascular Surgery Specialist

The heart muscle is strong enough to pump blood to all parts of the body.

The heart has a muscle structure that works continuously and contractes for life. In normal people, it contractes around 70 - 80 times per minute, which means that the heart beats nearly 5.000 times an hour, 2 - 3 billion times in an average lifetime. The heart pumps 5,5 liter blood into the body in 1 minute, which means 8 tons in 1 day and 240 thousand tons in 80 years. It is calculated that the total length of arteries, veins and capillary vessels that surround our body like nets is 100 thousand km, which means that if lined up, they could wrap around the Earth 2,5 times.

The biggest cause of deaths in the world and in our country is the circulatory system, i.e. cardiovascular diseases. One-third of the causes of death in the world and in our country are caused by cardiovascular diseases. According to 2019 data, 36.8% of deaths in our country are caused by cardiovascular diseases; 39.1% of them are due to hearth attack, 22.2% of them are due to cerebrovascular embolism, i.e. strokes and seizure, 25.7% of them are due to other cardiovascular diseases.

Trying to protect our heart, source and top fountain of life, and our vessels, namely, branches distributing life is our hand. If no arteriosclerosis, blocking our coronary arteries that feed our hearth and arteries that feed our organs, was in question, people could have lived healthy for at least 150 years. 60% of deaths due to cardiovascular diseases are caused by heart attack due to blockage of coronary vessels and stroke, namely seizure, due to blockage of the brain vessels. At the end of the 19th century, the famous medical scientist William Osler said “People are as old as their arteries.” This expression was not said in vain, those who have early blockage and arteriosclerosis appear older than their peers and complete the race for life earlier.

The most common and known disease of heart diseases is heart attack due to coronary artery disease, and the most important and known diseases of vascular diseases is stroke, embolism due to brain artery blockage; also gangrene and foot amputation developing due to leg artery blockage. Some of the risk factors that cause and facilitate the development of arteriosclerosis, which is commonly seen and the basis of the diseases leading even to death, are diabetes, high LDL cholesterol, low HDL cholesterol, high blood pressure, lack of physical movement, obesity and stressful life. These risk factors we specified are treatable or to some extent changeable. And there are risks that cannot be changed and controlled by us. These are age, gender and genetic familial factors. Arteriosclerosis is especially common in men after the age of 40, and more likely in those with a family history of heart attacks, stroke, arteriosclerosis.

Tips for a Healthier and Longer Life:
√ Exercising Regularly,
√ Playing Sports Regularly,
√ Balanced and Regular Nutrition,
√ Keeping Away From Stress,
√ Controlling Blood Sugar,
√ Be aware of risk factors,
√ Walk briskly for 30 minutes at least 5 days a week.

-Be aware of risk factors.
-Move.
-Walk briskly for 30 minutes at least 5 days a week.

TEI-TS1400
TURBOSHAFT ENGINE

TUSAŞ MOTOR SANAYİİ A.Ş.
TUSAŞ ENGINE INDUSTRIES, INC.

TS1400

ACCESSORY SYSTEMS AND ACCESSORY GEAR BOX

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(2-Stage Radial)

COMBUSTION CHAMBER
(Reverse Flow)

HP TURBINE
(2-Stage Axial)

POWER TURBINE
(2-Stage Axial)

TECHNICAL SPECIFICATIONS

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  1,400 shp
- **SLS ISA 30 sec OEI Power**
  1,660 shp
- **TO Power / Weight**
  8.54 (shp) / (kg)
- **Service Celling**
  20,000 ft
- **Output Shaft Speed**
  23,000 rpm

GÖKBEY
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