Project Internship
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Guide

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Table of Contents

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Scope of the Internship

1) To design the Main Pump, an important component in the flight control system of HAL's LCA Tejas.
2) To perform a feasibility study on the design of the pump so as to determine whether it can be indigenously produced in India.
3) To study about the various components present in an aircraft and their functionalities.
4) To study all the processes required to manufacture, assemble, test and deliver HAL Tejas.
5) To briefly study the workings of aircraft industry and the way HAL manages to meet the needs of its customers.

Hindustan Aeronautics Limited

Introduction

Hindustan Aeronautics Limited (HAL) is an Indian state-owned aerospace and defence company headquartered in Bangalore, India. It is governed under the management of the Indian Ministry of Defence. The government-owned corporation is primarily involved in the operations of the aerospace and is currently involved in the design, fabrication and assembly of aircraft, jet engines, helicopters and their spare parts. It has several facilities spread across India including Nasik, Korwa, Kanpur, Koraput, Lucknow, Bangalore, Hyderabad and Kasaragod.

History

HAL's history can be broadly divided into 3 parts.

1. Before Independence (1940-1947)

- HAL was established as Hindustan Aircraft Limited in Bangalore and was rapidly inducted into Military operations for the Allied forces in order to aid British forces in Asia to counter the threat of Imperial Japan. It was managed by the Indian Government, which bought out the stakes of the original founders. The first aircraft to be built was a Harlow PC-5.
- In 1943, the Bangalore factory was handed over to the United States Army Air Forces, to act as a prominent base in Asia, during which time it expanded rapidly and became a major overhaul and repair station for American aircraft called the 84th Depot. When it was returned to Indian control, it had become one of the largest overhauls and repair stations in the East.
- After the war, it resorted to making railway carriages as an interim activity.

2. After Independence (1947-1980s)

- After Independence, the management of operations was handed over to the Government of India.
- In 1957, it started manufacturing Bristol Siddeley Orpheus Engines under license.
- The HAL (Hindustan Aeronautics Limited) we know now was established in 1964, when it joined a consortium of IAF factories, which were planning on building MiG-21s under license.
- It also built the Cheetah and Chetak helicopters, under license, during this time.
- It also developed India's first indigenous aircraft, HF-24 Marut, which first entered military service in 1967 and played a crucial role in the 1971 Indo-Pak war.

3. Indigenous HAL (the 1980s - Present)

- During this time, HAL concentrated its efforts into developing and manufacturing new indigenous aircraft. This resulted in a rapid increase in activities by the HAL. The birth of the LCA Tejas and utility copter Dhruv can be traced back to the 1980s.
- It also modernized the MiG-21 by building an advanced version of it, called the MiG-21 *Bison*, which increased its lifespan.
- Several multi-million-dollar contracts were sealed between HAL and various international aerospace firms like Airbus, Boeing and Honeywell to produce spare parts and engines.
- Though lately there have been delays on the production front, the indigenization drive from 2017 has placed a greater emphasis in the development of new models. HAL is striving to meet all its goals and modernize the Indian Air Force with its new fleet of modern vehicles, like Tejas Mk1A and Mk2, Kamov 226T helicopters. It also plans to modernize Su-30I, Jaguars, Mirage and Hawk jets for better combat power.

Current Operations

One of the largest aerospace companies in Asia, HAL has annual turnover of over US$2 billion. More than 40% of HAL's revenues come from international deals to manufacture aircraft engines, spare parts, and other aircraft materials. A partial list of major operations undertaken by HAL includes the following:

- The US$35 billion fifth-generation fighter jet programme with the Sukhoi Corporation of Russia.
- US$1 billion contract to manufacture aircraft parts for Boeing.
- Multi-role transport aircraft project with Ilyushin of Russia worth US$600 million.
- 120 RD-33MK turbofan engines to be manufactured for MiG-29K by HAL for US$250 million.
- Contract to manufacture 1,000 TPE331 aircraft engines for Honeywell worth US$200,000 each (estimates put total value of deal at US$200 million).
- US$120 million deal to manufacture Dornier 228 for RUAG of Switzerland.

- Manufacture of aircraft parts for Airbus SAS worth US$150 million.
- US$100 million contract to export composite materials to Israel Aircraft Industries.
- US$65 million joint-research facility with Honeywell and planned production of Garrett TPE331 engines
- US$50.7 million contract to supply Advanced Light Helicopter to Ecuadorian Air Force. HAL will also open a maintenance base in the country.
- US$30 million contract to supply avionics for Malaysian Su-30MKM.
- US$20 million contract to supply ambulance version of HAL Dhruv to Peru.
- Contract of 3 HAL Dhruv helicopters from Turkey worth US$20 million.
- US$10 million order from Namibia for HAL Chetak and Cheetah helicopters.
- Supply of HAL Dhruv helicopters to Mauritius' National Police in a deal worth US$7 million.
- Unmanned helicopter development project with Israel Aircraft Industries.
- 220 Sukhoi Su-30MKI being manufactured at HAL's facilities in Nasik, Koraput and Bangalore. The total contract, which also involves Russia's Sukhoi Aerospace, is worth US$3.2 billion.
- 200 HAL Light Combat Helicopters for the Indian Air Force and 500 HAL Dhruv helicopters worth US$5.83 billion.
- US$900 million aerospace hub in Andhra Pradesh.
- US$57 million upgrade of SEPECAT Jaguar fleet of the Indian Air Force.
- US$55 million helicopter simulator training facility in Bangalore in collaboration with Canada's CAE.
- 64 MiG-29s to be upgraded by HAL and Russia's MiG Corporation in a programme worth US$960 million.
- Licensed production of 82 BAe Hawk 132.

HAL - Tejas

Introduction

HAL Tejas is a single engine, delta wing, highly agile, multi-role light supersonic fighter. It has a quadruplex digital fly-by-wire Flight Control System (FCS) with associated advanced flight control laws. The aircraft with delta wing is designed for ‘air combat’ and ‘offensive air support’ with ‘reconnaissance’ and ‘anti-ship’ as its secondary roles. It is the smallest and lightest fighter aircraft in its class of contemporary supersonic combat aircraft and is the second supersonic fighter to be developed by HAL (after Marut). Extensive use of advanced composites in the airframe gives a high strength to weight ratio, long fatigue life and low radar signatures.
Aeronautical Development Agency is the designated project manager for the development of LCA.
It is assembled on HAL Campus in an area dedicated to it, known as **LCA-Tejas** division (Light Combat Aircraft - Tejas).

HAL Tejas v/s JF 17 Thunder

The JF 17 took its first flight in August 2003 but it wasn’t introduced for military function till March 12th, 2007. The JF 17 Thunder is made jointly by Pakistan and China. China has been producing JF 17 Thunder since 2007 while Pakistan has been producing them since 2008. China doesn’t actually fly this aircraft. They export them to Nigeria and Myanmar. Several other countries like Egypt, Iran, Algeria have also shown interest in this aircraft. On the other hand, the HAL Tejas’ first flight was in 2001 but it wasn’t officially introduced until 2015. The first phase of development of HAL Tejas began as early as in 1993. As for the JF 17, Lockheed Martin was heavily involved in its manufacture. The US withdrew from the involvement in the production of JF 17 when India successfully completed its second nuclear test in 1998.
The first flying squadron of the JF 17 was the No, 26 Black Spiders which was fully formed on February 18th, 2007 with a strength of 14 fighters. Currently Pakistan has about 99 of them. The HAL Tejas’ first full squadron for the IAF is the No.45 Flying Dragons which formed on July 1st, 2016 which so far has 12 aircrafts and 4 trainers. Currently, only India uses this fighter aircraft, but it has plans to sell it to its friendly countries. In January 2019, Malaysia had shown interest in the HAL Tejas.

The JF 17 has 3 variants. JF 17 block 1 and JF 17 block 2 which has improved avionics, enhanced load carrying capacity and electronic warfare abilities. The original one didn’t have an air refuelling capacity which has been corrected in the block 2 version. The most recent version, the block 3 is the most recent one in which they added a helmet mounted multifunction display, improvements to the radar and infrared in 2017. There also exists JF 17B which is a two seater version, which has better surveillance capabilities and is also used for training purposes. As for HAL Tejas, only one type is currently used by the military which is the Mark 1. There exist prototype variants of Mark 1A with improved AESA Israeli radar. The first original version of HAL Tejas didn't have air refuelling capabilities, which are present in the Mark 1A version. The Mark 1A is also a ton lighter than the Mark 1 and more maintenance friendly. There exists the Navy version Mark 1 also. A Mark 2 is also in the idea phase which won't be completed till 2022, which will have a more powerful engine which will allow higher payload capacity. It will also have radar, infrared and on-board oxygen facility improvements.

Specification	PAF JF 17 Thunder Block 1	IAF HAL Tejas Mark 1
Length (m)	14.93	13.20
Wingspan (m)	9.48	8.20
Height (m)	4.72	4.40
Maximum takeoff weight (lb)	29750	29100
Maximum speed (in Ma number)	1.6	1.8
Maximum flying height (ft)	55500	52500
Operational Range including drop tanks (km)	1352	1750
Guns	1x23 twin barrel cannon (GSH23)	1x23 twin barrel cannon (GSH23)
Usable missile types	air to air, air to surface and anti ship	air to air, air to surface and anti ship
Usable bomb types	Guided and unguided	Laser guided and unguided
No. of hard points	7 (4 under wings, 2 under tip and 1 under the fuselage)	8 (6 on the wings, 1 under the fuselage and 1 beneath the portside intake trunk)
Maximum no. of drop tanks	3	2
Cost	25 million USD (block 1) 32 million USD (block 3) (unofficial)	23 million USD (Mark 1) 64 million USD (Mark 1A)(fully upgraded)

Necessity and Birth of Tejas (In 4 Stages)

Stage 1

In 1969, the Indian government accepted the recommendation by its Aeronautics Committee that Hindustan Aeronautics Limited (HAL) should design and develop a fighter aircraft around a proven engine. Based on a 'Tactical Air Support Aircraft' ASR markedly similar to that for the Marut, HAL completed design studies in 1975, but the project fell through due to inability to procure the selected "proven engine" from a foreign manufacturer and the IAF's requirement for an air superiority fighter with secondary air support and interdiction capability remained unfulfilled.

Stage 2

In 1983, IAF realised the need for an Indian combat aircraft for two primary purposes. The principal and most obvious goal was to replace India's ageing MiG-21 fighters, which had been the mainstay of the IAF since the 1970s. The "Long Term Re-Equipment Plan 1981" noted that the MiG-21s would be approaching the end of their service lives by the mid-1990s and that by 1995, the IAF would lack 40 % of the aircraft needed to fill its projected force structure requirements. The LCA programme's other main objective was an across-the-board advancement of India's domestic aerospace industry. The value of the aerospace "self-reliance" initiative is not simply the aircraft's production, but also the building of a local industry capable of creating state-of-the-art products with commercial spin-offs for a global market.

Stage 3

In 1984, the Indian government chose to establish the Aeronautical Development Agency (ADA) to manage the LCA programme. While the Tejas is often described as a product of Hindustan Aeronautics Limited (HAL), responsibility for its development belongs to ADA, a national consortium of over 100 defence laboratories, industrial organisations, and academic institutions with HAL being the principal contractor. The government's "self-reliance" goals for the LCA included the three most sophisticated and challenging systems

1) The fly-by-wire (FBW) flight control system (FCS)
2) Multi-mode pulse-doppler radar
3) Afterburning turbofan engine.

Stage 4

The IAF's Air Staff Requirement for the LCA were not finalised until October 1985. This delay rendered moot the original schedule which called for first flight in April 1990 and service entry in 1995; however, it also gave the ADA time to better marshal national R&D and industrial resources, recruit personnel, create infrastructure, and to gain a clearer perspective of which advanced technologies could be developed locally and which would need to be imported.

Project definition commenced in October 1987 with France's Dassault-Breguet Aviation as consultants. Dassault-Breguet was to assist in the design and systems integration of the aircraft, with 30 top-flight engineers reported to have flown to India to act as technical advisers to IADA, in exchange for $100m / ₹560 crore (equivalent to ₹52 billion or US$760 million in 2018), this phase was completed in September 1988.

LCA Program (In 2 phases)

A review committee was formed in May 1989, which reported that infrastructure, facilities and technologies in India had advanced sufficiently in most areas and that the project could be undertaken. A two-stage full-scale engineering development (FSED) process was opted for. In 1990, the design was finalised using the "control configured vehicle" concept to define a small tailless delta winged aircraft with relaxed static stability (RSS) for enhanced manoeuvrability.

Phase 1

Phase 1 commenced in April 1993, and focused on "proof of concept" and comprised the design development and testing (DDT) of two technology demonstrator aircraft which were named as TD-1 and TD-2. This would be followed by the production of two prototype vehicles (PV-1 and PV-2), TD-1 finally flew on 4 January 2001. FSED Programme Phase-I was successfully completed in March 2004 and cost ₹2,188 crore.

The relaxed static stability (RSS) was an ambitious requirement. In 1988, Dassault had offered an analogue flight control system (FCS), but the ADA recognised that digital FCSs would supplant it. First flying in 1974, the General Dynamics F-16 was the first production aircraft designed to be slightly aerodynamically unstable to improve manoeuvrability.
In 1992, the LCA National Control Law (CLAW) team was set up by the National Aeronautics Laboratory to develop India's own state of the art fly-by-wire FCS for the Tejas. In 1998, Lockheed Martin's involvement was terminated due to a US embargo in response to India's second nuclear tests in May of that year.

Another critical technology is the multi-mode radar (MMR). The Ericsson/Ferranti PS-05/A I/J-band multi-function radar was initially intended to be used,[31] as used on Saab's JAS 39 Gripen. However, after examining other radars in the early 1990s, the Defence Research and Development Organisation (DRDO) became confident that local development was possible. HAL's Hyderabad division and the Electronics and Radar Development Establishment (LRDE) were selected to jointly lead the MMR programme, and work commenced in 1997. The DRDO's Centre for Airborne System (CABS) is responsible for the MMR's test programme. Between 1996 and 1997, CABS converted the surviving HAL/HS-748M Airborne Surveillance Post (ASP) into a test bed for the LCA's avionics and radar.

The NAL's CLAW team completed integration of the flight control laws by themselves, with the FCS software performing flawlessly for over 50 hours of pilot testing on TD-1, resulting in the aircraft being cleared for flight in January 2001. The automatic flight control system (AFCS) has been praised by all test pilots, one of whom remarked that he found the LCA easier to control during take-off than a Mirage 2000.

Phase 2

Phase 2 commenced in November 2001, and consisted of the manufacturing of three more prototype vehicles (PV-3, PV-4 and PV-5), leading to the development of the final variant that would join the air force and the navy and 8 Limited Series Production (LSP) aircraft, and establishment of infrastructure for producing 8 aircraft per year. The phase cost ₹3,301.78 crore, and an additional amount of ₹2,475.78 crore was given for induction into Indian Air Force by obtaining IOC and FOC. The total cost for development of Tejas (including PDP, Phase 1 and Phase 2) was ₹7,965.56 crore as of August 2013.

By mid-2002, the MMR had reported suffered major delays and cost escalations. By early 2005, only the air-to-air look-up and look-down modes — two basic modes — were confirmed to have been successfully tested. In May 2006, it was revealed that the performance of several modes being tested "fell short of expectations." As a result, the ADA was reduced to running weaponization tests with a weapon delivery pod, which is not a primary sensor, leaving critical tests on hold. According to test reports, there was a serious compatibility issue between the radar and the LRDE's advanced signal processor module (SPM). Acquisition of an "off-the-shelf" foreign radar is an interim option being considered.

Of the five critical technologies the ADA identified at the beginning of the programme as required to design and build a new fighter, two have been successful: the development and manufacture of carbon-fibre composite (CFC) structures and skins, and a modern glass cockpit. ADA has a profitable commercial spin-off in its Autolay integrated automated software for designing 3-D laminated composite elements (which has been licensed to both Airbus and Infosys). By 2008, 70% of the LCA's components were being manufactured in India, the dependence on imported components was stated to be progressively reduced over time. However, problems were encountered with the other three key technology initiatives. For example, the intended engine, the GTRE GTX-35VS Kaveri, had to be replaced with an off-the-shelf "foreign" engine, the General Electric F404.

Prototypes, Limited Serial Production (LSP) and Testing

In March 2005, the IAF placed an order for 20 aircraft, with a similar purchase of another 20 aircraft to follow. All 40 were to be equipped with the F404-GE-IN20 engine. In December 2006, a 14-member "LCA Induction Team" was formed at Bangalore to prepare the Tejas and assist with its introduction into service.

On 25 April 2007, the first Limited Series Production (LSP-1) Tejas performed its maiden flight, achieving a speed of Mach 1.1 (1,347.5 km/h; 837.3 mph). The Tejas completed 1,000 test flights and over 530 hours of flight testing by 22 January 2009. In 2009, a Tejas achieved a speed of over 1,350 kilometres per hour (840 mph) during sea level flight trials at INS Hansa, Goa.

On 16 June 2008 LSP-2 made its first flight followed by the first flight of the trainer variant in November 2009. On 23 April 2010, LSP-3 flew with a hybrid version of the Elta EL/M-2032 multi-mode radar; in June 2010, LSP-4 made its maiden flight in an IAF Initial Operating Clearance (IOC) configuration. By June 2010, the Tejas had completed the second phase of hot weather trials in an IOC configuration with the weapons system and sensors integrated. Sea trials were also being carried out. On 19 November 2010, LSP-5 with IOC standard equipment started flight trials.

In December 2009, the government sanctioned ₹8,000 crore to begin production of the fighter for the Indian Air Force and Indian Navy. The Indian Navy has a requirement for 50 Tejas aircraft and the first prototype, NP-1 was rolled out in July 2010. IAF ordered 20 additional Tejas fighters after the defence acquisition council cleared the plan. In December 2014 the LCA Navy successfully conducted ski-jump trials at SBTF Goa. The navy variant has a special flight control law mode. It controls a hands-free take-off, which reduces the pilot workload, as the ramp launches the aircraft on an upward flight path.

In November 2010, it was reported that the Tejas Mk 1 reportedly fell short of the relaxed Air Staff Requirements stipulated for limited series production (LSP) aircraft.
The areas that did not meet requirements were

a) Power to weight ratio
b) Sustained turning rate
c) Maximum speeds at low altitudes
d) AoA range
e) Weapon delivery profiles

* the extent of the deficiencies was classified.

On 9 March 2012, LSP-7 took to its maiden flight from HAL airport. The Naval LCA made its first flight, almost two years after being rolled out, on 27 April 2012.

In September 2011, weapons tests, including bombing trials, began at Pokhran range, to be followed by missile trials at Goa. On 27 June 2012, three Tejas (LSP 2, 3 and 5) aircraft completed bombing runs in the desert of Rajasthan, using precision laser-guided 1,000 lb bombs and unguided bombs. The Tejas had completed 1,941 flights by July 2012.

In the latter half of 2012, the Tejas was grounded for over three months due to a serious safety issue which arose with the introduction of a new pilots' helmet, which protruded above the ejection seat. There was concern that, during an ejection, the helmet would strike the canopy before the canopy was released. Flight tests resumed in November 2012 after the ejection system had been modified. LSP 8 had a successful maiden test flight on 31 March 2013, and the programme had completed 2,418 test flights by 27 November 2013. On 31 March 2013, LSP-8 took to its maiden flight from HAL airport. On 8 November 2014, PV-6(KH-T2010), a trainer variant, completed its first test flight.

Out of a total of 35 major avionics components and line-replaceable units (LRUs), only three involve foreign systems.
These are:

1) The multi-function displays (MFDs) by Sextant (France)
2) Elbit (Israel), the helmet-mounted display and sight (HMDS) cueing system by Elbit,
3) The laser pod supplied by Rafael (Israel).

Production aircraft are expected to have MFDs from Indian suppliers. A few important items of equipment (such as the Martin-Baker ejection seat) have been imported. As a consequence of the embargo imposed on India after its nuclear weapons tests in May 1998, many items originally planned to be imported were instead developed locally; these sanctions contributed to the prolonged delays suffered by the LCA.

Problems Tackled and Operational Clearance

The IAF plans to raise the first squadron in Bangalore to iron out issues with ADA and HAL, and eventually base these fighters at Sulur Air Force Station, Coimbatore in the southern state of Tamil Nadu. Tejas' Final Operational Clearance (FOC) was repeatedly delayed since 2011 and was finally achieved on 20 February 2019.

HAL was instructed by the Indian government to strictly adhere to deadlines to ensure Initial Operational Clearance-II by the end of 2013 and Final Operational Clearance (FOC) by the end of 2014. On 20 December 2013, the IOC-II was issued, after which the aircraft was cleared to be flown by regular IAF pilots and begin induction into squadron service. The first squadron of 18 to 20 Tejas will be based at Sulur Air Force Station, Coimbatore in the state of Tamil Nadu, and it will work to achieve FOC by December 2014. To fulfil the IOC-II standard, the aircraft was certified to carry close to three tons of weapons which include laser-guided 500 kg bombs and short-range R-73 missiles, reach top speeds of 1,350 km per hour, withstand turns up to 7 g, reach angle of attack of 24 degrees (from 17 degrees initially), and have an operational radius of 400–500 km.

To obtain FOC, the fighter will have to be certified for six more criteria.

1) Integration of Derby and Python BVR missiles weighing 150 kg, with a range of 70 km
2) A Gryazev-Shipunov GSh-23 gun will be undertaken.

3) An air-to-air refuelling probe supplied by Cobham will be added.
4) The angle of attack will be increased from 24 to 28 degrees
5) The braking system will be enhanced
6) The existing nose cone radome made of composites will be replaced by a quartz model in a bid to increase the current radar range of 45–50 km to more than 80 km.

These modifications were expected to be completed within 15 months of IOC-II. To expand the flight envelope to meet service requirements, the programme enlisted assistance from EADS.

The Final Operational Clearance (FOC) campaign began in December 2013, with three aircraft from Tejas flight-line successfully completing advanced weapon trials. The campaign was held in Jamnagar. New weapons were integrated on the aircraft. As part of the FOC, the aircraft is being readied for all-weather trials in Bangalore and in Gwalior. Tejas took its maiden flight in January 2001, and by December 2013, it had completed 2,587 sorties covering over 1,750 hours. In July 2014, the FOC was pushed back as six or more aircraft were needed for testing and only one had been produced then. Tejas received IOC-II clearance on 17 January 2015.

In May 2015, the Mk 1 aircraft was criticised by the Comptroller and Auditor General of India (CAG) for not meeting IAF requirements, such as a lack of a two-seat trainer, electronic warfare capabilities, the Radar Warning Receiver/Countermeasure Dispensing System, weight increases, reduced internal fuel capacity, non-compliance of fuel system protection, forward-facing pilot protection, and reduced speed. Most of these issues are expected to be rectified in the future Mk 2 version.

In October 2015, IAF has confirmed that it had ordered 120 (six squadrons) of Tejas Mk 1A, triple the 40 aircraft it had previously committed to buying. It was reported that IAF agreed to accept 40 aircraft even though the CAG had found serious operational shortfalls, including engine thrust, weight and pilot protection in front against 7.62 mm rifle calibre rounds. The IAF agreed to accept the initial Tejas aircraft with some deficiencies to keep the programme going; the DRDO and HAL promised an improved Tejas Mk 1A version; changes to the ballast and landing gear will reduce its weight by 1,000 kg and the delivery will begin by 2016. Tejas Mk 1A shall also have electronic warfare equipment, better air to air capability, aerial refuelling and improved ease of maintenance.

In February 2016, LSP-7 test-fired the BVRAAM Derby missile on a BNG (Ballistic Non Guided) mode in Jamnagar as part of its scheduled weapon trials. These weapon trials are part of the Final Operational Clearance (FOC) mandate. It was the 169th flight of LSP-7. The aircraft is also scheduled to fire a Close Combat Missile (CCM) Python-5 as part of the FOC trials. The LSP-7 along with LSP-4 were part of Indian flying assets at the Bahrain International Air Show (BIAS-2016).

On 26 February 2016, Defence Minister Manohar Parrikar said in the Lok Sabha that the Indian Air Force will accept three to four Tejas this year and stand up a total of eight squadrons in eight years. He also said, "We are also in the process of approving the second line of manufacturing to the HAL so that they can produce 16 aircraft per year." On 7 November 2016, Parrikar approved procurement of 83 Tejas for IAF, at a cost of ₹50,025 crore.

In December 2016, the Indian Navy announced that the fighter is overweight, and they will look for other alternatives. The Indian Navy eventually issued an RFI for 57 naval multirole fighters.

On 12 May 2017, Tejas successfully demonstrated an Air-to-Air Beyond Visual Range (BVR) missile firing capability by releasing Derby Air-to-Air BVR missile in RADAR guided mode. The missile launch was performed in lock-on after launch mode. The missile destroyed its manoeuvrable aerial target with pinpoint precision at the Interim Test Range, Chandipur in Odisha.

In November 2017, it was reported that the Indian Air Force told the government that the Tejas is inadequate for the single-engine fighter program with insufficient flight endurance, smaller payload capacity, increased maintenance hours, and higher costs for maintenance compared to other contenders aircraft.

In February 2018, refuelling of Tejas with the engine running—known as "hot refuelling"—was carried out. Hot refuelling capability is one of the requirements for Tejas Mk 1A and is expected to shorten the turnaround time between sorties.

In August 2018, the naval variant of the Tejas conducted its first "taxi-in" engagement on a naval platform in Goa to prove its hook-arrester system. The Indian Defence Minister, Nirmala Sitharaman's backing of the Tejas programme allowed the restarting of tests and gave its naval variant a fresh lease on life.

In September 2018, Tejas successfully completed the trials for mid air refuelling, which is one of the key items required for the aircraft to obtain FOC. In January 2019, HAL received permission from CEMILAC to start production of FOC standard Tejas, despite the certification not being awarded yet.

On 20 February 2019, during Aero India 2019, Final Operational Clearance was formally awarded to Tejas.

Inter-Department Coordination in HAL, Tejas

IAF places an order and gives guidelines regarding the aircraft
ADA drafts a design based on guiding principles with the help of ARDC
Design goes through scrutiny and various modifications
Technology demonstrators are produced by ADA and ARDC to fly primarily using a proven engine
Based on the TDs, limited prototypes are produced to meet the guidelines
Based on the success of the prototypes, LSPs (Limited Series Production) are made
The finalised design is sent to DLE (Design Liaison Engineering / Indigenization dept)

- DLE, after thoroughly analyzing the design, forwards it to Methods dept
- Methods department devises the functions to be carried out by various departments
- Tool department takes care of designing, manufacturing and obtaining necessary tools
- IMM department takes care of inventory management i.e. ordering the raw materials, outsourcing several parts etc
- Production line department takes care of main line of fuselages in hangars
- LRU department takes care of assembling all the Light Replaceable Units in the aircraft
- DGQCA which is a third party evaluating organisation verifies the production in every phase and gives a clearance to be processed further

Design

Important parts of an Aircraft Airframe

Some of the important parts in the air-frame of the aircraft are as follows

Fuselage

Fuselage is an is an aircraft’s main body section.

Types of fuselages in practice

1) **Truss structure**
   This type of structure is still in use in many lightweight aircraft using welded steel tube trusses.

2) **Monocoque**
   In this method, the exterior surface of the fuselage is also the primary structure.

3) **Semi-Monocoque**
   In this type of fuselage, first, a series of frames in the shape of the fuselage cross sections are held in position on a rigid fixture. These frames are then joined with lightweight longitudinal elements called stringers. These are in turn covered with a skin, attached by riveting or by bonding with special adhesives. The fixture is then disassembled and removed from the completed fuselage shell, which is then fitted out with wiring, controls, and interior equipment such as seats and luggage bins. Most modern large aircraft are built using this technique, but use several large sections constructed in this fashion which are then joined with fasteners to form the complete fuselage. As the accuracy of the final product is determined largely by the costly fixture, this form is suitable for series production, where a large number of identical aircraft are to be produced.

Semi-monocoque type fuselage is employed in HAL Tejas Series Production (SP) aircrafts.

Fuselage divisions

The fuselage is divided into three divisions.
The details of the components they house, the stations they are divided into and the lengths of each division are as follows

Front fuselage

It is 4.4 metres in length.
It is divided into numbered stations #1 to #20
It houses important components such as

a) Cockpit Control System
b) Ejection Seat
c) Windscreen
d) Canopy
e) Nose-Cone
f) Radar

Centre Fuselage

It is 3.0 meters in length.
It is divided into numbered stations #21 to #30
It houses important components such as

a) AMAGB (Aircraft Mounted Accessory Gearbox
b) Main Pump
c) Engine Driven Pump
d) Wing Attachment
e) 2 Fuel Tanks

Rear Fuselage

It is 33 metres in length.
It is divided into 8 stations numbered #31 to #38
It houses important components such as

a) Engine
b) EMDP (Electric Motor Driven Pump)

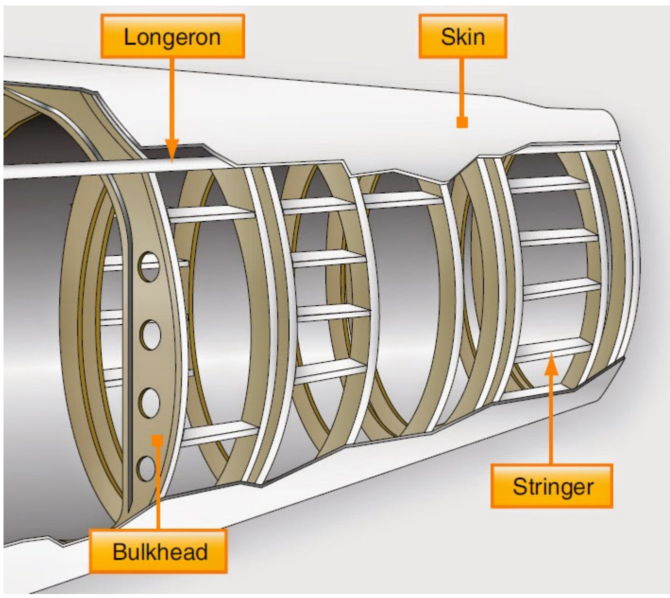
Wings

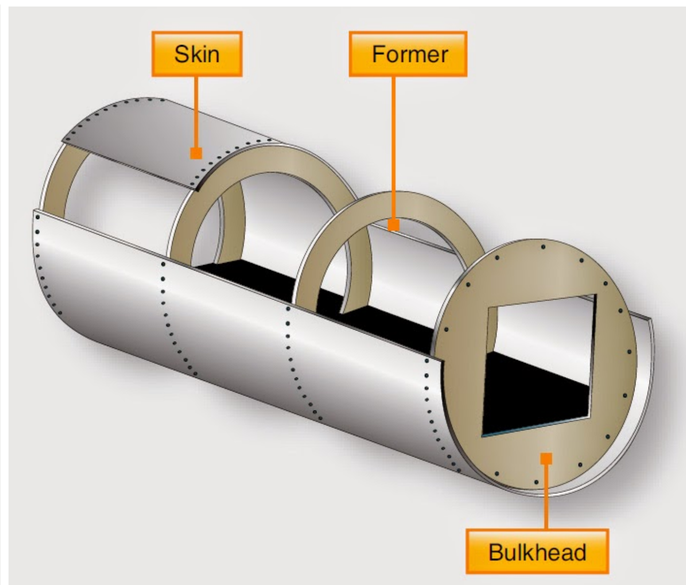
Each wing is 4.1 metres in length.
It houses important components such as

a) Electrical Lining which are used to control the drop tanks and missiles.
b) A fuel tank each.

Longeron/Stringer/Stiffener

It is a thin strap of material to which the skin of the aircraft is fastened.
In the fuselage, stringers are attached to the frames and run in the longitudinal direction of the aircraft





Former

A frame is a basic structure designed to bear a load.
It is a structural ring in an aircraft fuselage.

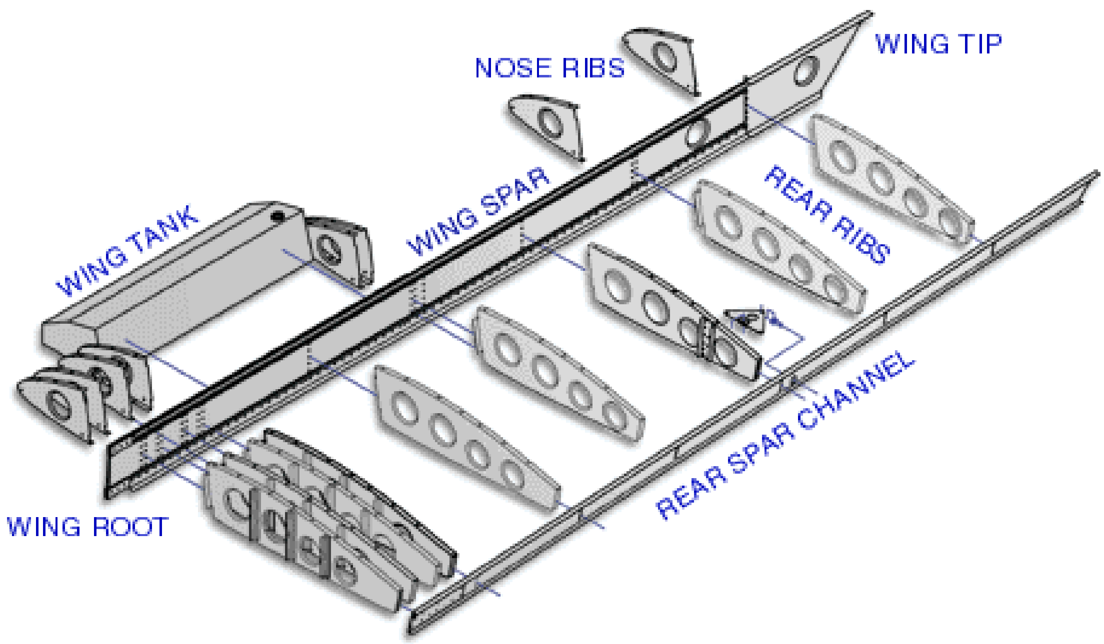
Bulkhead

A bulkhead is the physical partition that divides the plane into different sections.

Spar

Spar is the main structural member of the wing, running span wise at right angles to the fuselage.
The spar carries flight loads and the weight of the wing while on the ground which includes the structural weight of the wing as well as the fuel tanks in the wing.
There are two types of spars in the aircraft wing frame namely

1) Wing Spar
2) Rear Spar



Ribs

Ribs are the forming elements of the structure of the wing.
The ribs attach to the main spar, and by being repeated at frequent intervals, form a skeletal shape of the wing.
There are two types of ribs in an aircraft wing namely

1) Nose Ribs
2) Rear Ribs

Elevon
Elevons or tailerons are aircraft control surfaces that combine the functions of the elevator (used for pitch control) and the aileron (used for roll control), hence the name. They are frequently used on tailless aircraft such as flying wings. An elevon that is not part of the main wing, but instead is a separate tail surface, is a stabilator.
Elevons are installed on each side of the aircraft at the trailing edge of the wing. When moved in the same direction (up or down) they will cause a pitching force (nose up or nose down) to be applied to the airframe. When moved differentially, (one up, one down) they will cause a rolling force to be applied. These forces may be applied simultaneously by appropriate positioning of the elevons e.g. one wing's elevons completely down and the other wing's elevons partly down.

Fin

The vertical stabilizers, vertical stabilisers, or fins, of aircraft, missiles or bombs are typically found on the aft end of the fuselage or body, and are intended to reduce aerodynamic side slip and provide direction stability. It is analogous to a skeg on boats and ships.

Rudder
A rudder is a primary control surface used to steer an aircraft.

Slat
Slats are aerodynamic surfaces on the leading edge of the wings of fixed-wing aircraft which, when deployed, allow the wing to operate at a higher angle of attack. A higher coefficient of lift is produced as a result of angle of attack and speed, so by deploying slats an aircraft can fly at slower speeds, or take off and land in shorter distances. They are usually used while landing or performing manoeuvres which take the aircraft close to the stall, but are usually retracted in normal flight to minimize drag. They decrease stall speed.

Radome
A radome (which is a portmanteau of radar and dome) is a structural, weatherproof enclosure that protects a radar antenna. The radome is constructed of material that minimally attenuates the electromagnetic signal transmitted or received by the antenna, effectively transparent to radio waves. Radomes protect the antenna from weather and conceal antenna electronic equipment from view. They also protect nearby personnel from being accidentally struck by quickly rotating antennas.

Material used in HAL Tejas

Tejas is constructed of aluminium-lithium alloys, carbon-fibre composites, and titanium alloys. Composite materials make up 45% of the airframe by weight and 95% by surface area. Upper and lower wing skins are manufactured from a single piece of carbon-fibre reinforced polymer. Wing spars and ribs are also made out of carbon composites.

The percentage of carbon composites in the airframe by weight rose from 30% in the technology demonstrators to 42% in the prototype vehicles. The construction of elevons, tailfin, rudder, air brakes and landing gear doors use co-cured and co-bonded manufacturing techniques. The radome is made out of Kevlar, while the fin tip is made out of glass-fibre reinforced plastic. Composite materials are used to make an aircraft lighter compared to an all-metal design, and the LCA's percentage employment of carbon-fibre composites is one of the highest among contemporary aircraft of its class. Apart from making the plane much lighter, there are also fewer joints or rivets, which increases the aircraft's reliability and lowers its susceptibility to structural fatigue cracks. The wing and fin of the compound-delta aircraft are of carbon-fibre-reinforced polymer, and were designed to provide a minimum weight structure and to serve as integral fuel tanks. The tailfin is a monolithic honeycomb structure piece, reducing the manufacturing cost by 80% compared to the "subtractive" or "deductive" method, involving the carving out of a block of titanium alloy by a computerised numerically controlled machine. No other manufacturer is known to have made fins out of a single piece.

The use of composites resulted in a 40% reduction in the total number of parts, including half the number of fasteners required, compared to a metallic frame design. The composite design also helped to avoid about 2,000 holes being drilled into the airframe. Overall, the aircraft's weight is lowered by 21%. While each of these factors can reduce production costs, an additional benefit — and significant cost savings — is realised in the shorter time required to assemble the aircraft — seven months for the LCA as opposed to 11 months using an all-metal airframe. The wing-shielded, side-mounted air intakes are fixed-geometry with splitter plates.

In 2001 it was envisaged that the naval variant would have nose droop to provide improved view for carrier landings, and wing leading–edge vortex controllers (LEVCON) to increase lift during approach. The LEVCONs are control surfaces that extend from the wing-root leading edge and thus afford better low-speed handling for the LCA, which would otherwise be compromised by the increased drag that results from its delta-wing design. The LEVCONs should also increase controllability at high angles of attack (AoA). The naval Tejas will also have a strengthened spine, a longer and stronger undercarriage, and powered nose wheel steering for deck manoeuvrability. The Tejas trainer variant will have "aerodynamic commonality" with the two-seat naval aircraft design.

Avionics

The Tejas has a night vision goggles (NVG)-compatible "glass cockpit", dominated by an CSIR-CSIO domestically-developed head-up display (HUD), three 5 in x 5 in multi-function displays, two Smart Standby Display Units (SSDU), and a "get-you-home" panel providing the pilot with essential flight information in case of an emergency. The displays provide information on key flight systems and controls on a need-to-know basis, along with basic flight and tactical data. The pilot interacts with onboard systems through a multifunctional keyboard and several selection panels. The CSIO-developed HUD, Elbit-furnished DASH helmet-mounted display and sight (HMDS), and hands-on-throttle-and-stick (HOTAS) controls reduce pilot workload and increase situation awareness by allowing access to navigation and weapon-aiming information with minimal need to spend time "head down" in the cockpit.

The first 20 production Tejas Mk 1 equipped with hybrid version of the EL/M-2032 radar. It features look-up/look-down/shoot-down modes, low/medium/high pulse repetition frequencies (PRF), platform motion compensation, doppler beam-sharpening, moving target indication(MTI), Doppler filtering, constant false alarm rate (CFAR) detection, range-Doppler ambiguity resolution, scan conversion, and online diagnostics to identify faulty processor modules. The Tejas Mk 1A will be equipped with an improved version of the EL/M-2052 AESA radar being developed jointly by Elta and HAL.

The electronic warfare suite is designed to enhance combat survivability during deep penetration. The EW suite is developed by the Defence Avionics Research Establishment (DARE) with support from the Defence Electronics Research Laboratory (DLRL). This EW suite, known as Mayavi, includes a radar warning receiver (RWR), Missile Approach Warning (MAW) and a Laser warning receiver (LWR) system, Infrared & Ultraviolet Missile warning sensors, self-protection jammer, chaff, jaff and flares dispenser, an electronic countermeasures (ECM) suite and a towed radar decoy (TRD). In the interim, the Indian Ministry of Defence has revealed that an unspecified number of EW suites had been purchased from Israel's Elisra for the LCA prototypes.

Tejas is also to be equipped with an infra-red search and track (IRST) sensor, which can detect and track thermal energy emissions. This system shall be pod-based, additional sensor pods are to include drop tanks for ferry flight/extended range/loitering time, FLIR targeting pod, ECM pods, Flares/Infrared decoys dispenser pod and chaff pod, EO/IR sensor pod, LITENING targeting pods, forward looking infrared (FLIR) sensor, and a laser designator/laser rangefinder, which can be used in various capacities, including reconnaissance, training, or attack.

Flight Control

Since the Tejas is a relaxed static stability design, it is equipped with a quadruplex digital fly-by-wire flight control system to ease pilot handling. The Tejas aerodynamic configuration is based on a pure delta-wing layout with shoulder-mounted wings. Its control surfaces are all hydraulically actuated. The wing's outer leading edge incorporates three-section slats, while the inboard sections have additional slats to generate vortex lift over the inner wing and high-energy air-flow along the tail fin to enhance high-AoA stability and prevent departure from controlled flight. The wing trailing edge is occupied by two-segment elevons to provide pitch and roll control. The only empennage-mounted control surfaces are the single-piece rudder and two air brakes located in the upper rear part of the fuselage, one each on either side of the fin.

Engine

Early on, it was decided to equip the prototype aircraft with the General Electric F404-GE-F2J3 afterburning turbofan engine while a program to develop a domestic power plant led by the Gas Turbine Research Establishment was launched. In 1998, after Indian nuclear tests, US sanctions blocked sales of the F404, leading to a greater emphasis on the domestic Kaveri. In 2004, General Electric was awarded a US$105 million contract for 17 uprated F404-GE-IN20 engines to power the eight pre-production LSP aircraft and two naval prototypes; deliveries began in 2006. In 2007, a follow-on order for 24 F404-IN20 engines to power the first operational Tejas squadron was issued.

Cost overruns and delays were encountered in the Kaveri's development. In mid-2004, the Kaveri failed high-altitude tests in Russia, ruling out it powering the first production Tejas aircraft. In February 2006, the ADA awarded a contract to French engine company Snecma for technical assistance on the Kaveri. Using Snecma's new core, an uprated derivative of the Dassault Rafale's M88-2 engine, providing 83–85 kilo Newton (kN) of maximum thrust was being considered by DRDO. The IAF objected that since Snecma already developed the core of the engine, the DRDO will not be participating in any joint development but merely providing Snecma with an 'Indian-made' stamp. In November 2014, the DRDO was submitting documents to cancel development of Kaveri.

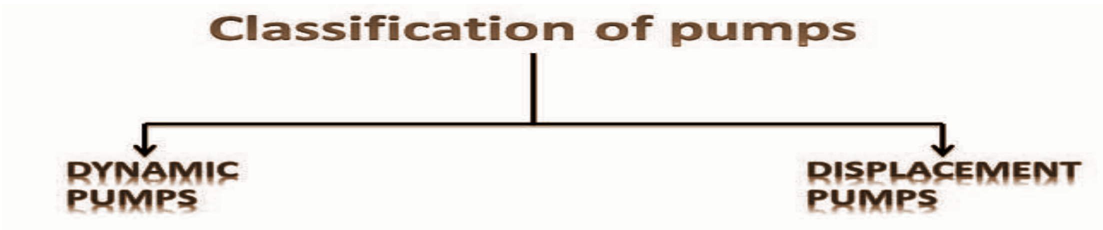
In 2008, it was announced that an in-production power plant would have to be selected; this was required to be in the 95 to 100 kilo Newton (kN) (21,000–23,000 lbf) range to execute combat manoeuvres with optimal weapons load. After evaluation and acceptance of technical offers for both the Eurojet EJ200 and the General Electric F414, the commercial quotes were compared in detail and GE's F414 was declared as the lowest bidder. The deal covered the purchase of 99 GE F414 engines, an initial batch will be supplied directly by GE and the remainder to be manufactured in India under a technology transfer arrangement. According to the IAF, adopting the new power plant required a three-to-four years of redesign work.

Performance

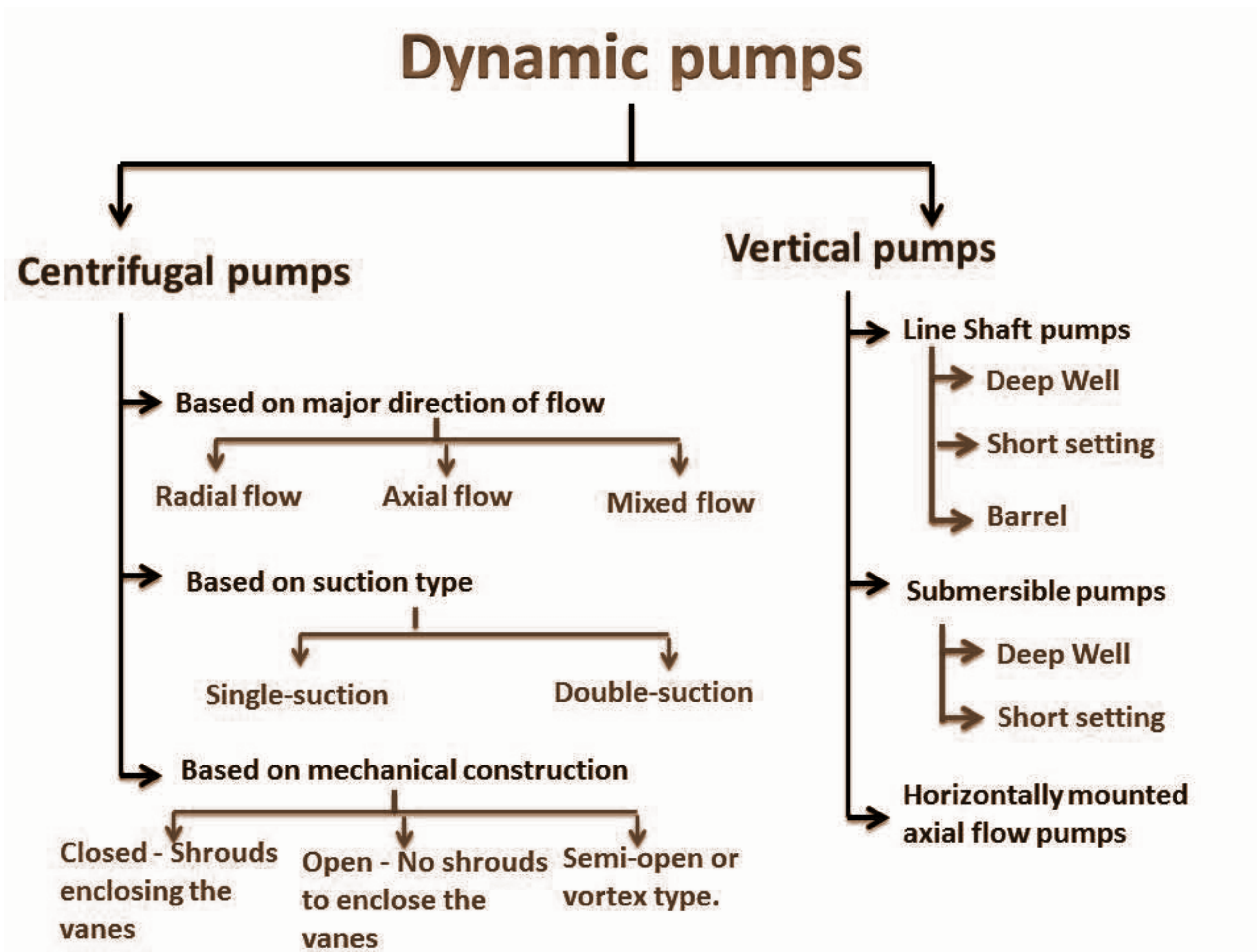
SPECIFICATION	MEASUREMENT
Length	13.2 m
Span	8.2 m
Height	4.4 m
Maximum Takeoff Weight	13.5 tons
Payload	5.3 tons
Speed	1.6 Ma
Radius Of Action	300 km
Takeoff Distance	1700 m
Landing Distance	1300 m
Service Ceiling	16 km

Pumps

Pumps can be classified into Dynamic Pumps and Displacement Pumps.



Dynamic pumps



Dynamic pumps impart velocity and pressure to the fluid as it moves past or through the pump impeller and, subsequently, convert some of that velocity into additional pressure. It is also called Kinetic pumps. Kinetic pumps are subdivided into two major groups and they are centrifugal pumps and positive displacement pumps.

Classification of Dynamic Pumps

A. Centrifugal Pumps

A centrifugal pump is a rotating machine in which flow and pressure are generated dynamically. The energy changes occur by virtue of two main parts of the pump, the impeller and the volute or casing. The function of the casing is to collect the liquid discharged by the impeller and to convert some of the kinetic (velocity) energy into pressure energy.

1. Radial Flow

The impeller discharges fluid at right angles to the shaft axis. In this centrifugal pump, pressure is developed wholly by centrifugal force. The radial type pumps are used for the application of high head and low discharge.

2. Mixed Flow

The flow direction is partly axial and partly radial. Hence has a result the flow is diagonal. The mixed flow type pumps are used for the application of medium head and high discharge. In this centrifugal pump, pressure is developed partly by centrifugal force and partly by the lift of the vanes of the impeller on the liquid.

3. Axial Flow

The flow through impeller is parallel to shaft axis low head and very high discharge. The axial flow type pumps are used for the application of medium head and high discharge. In this centrifugal pump, pressure is developed by the propelling or lifting action of the vanes of the impeller on the liquid.

4. Axial Split-Case Pumps

Axial split-case pumps have a casing that is split along the centreline of the shaft. The impellers can be readily exposed for service and inspection by removing the upper half of the casing. It is also called horizontal split or horizontal split-case pump. Axial-split pumps may be single stage or multistage for higher pressures. The pumps are usually mounted with shafts in the horizontal position, but vertically mounted pumps for reduced floor space are also available.

B. Vertical Pumps

Vertical pumps were originally developed for well pumping. The bore size of the well limits the outside diameter of the pump and so controls the overall pump design.
Vertical pumps can be subdivided into three major categories:

- Lines-shaft pumps
- Submersible pumps
- Horizontally mounted axial-flow pumps

1. Line-shaft Pumps

The driver is mounted on the discharge head for these type of motors. The line-shafting extend through the column to the bowl assembly and transmits torque to the pump rotor.

2. Submersible Pumps

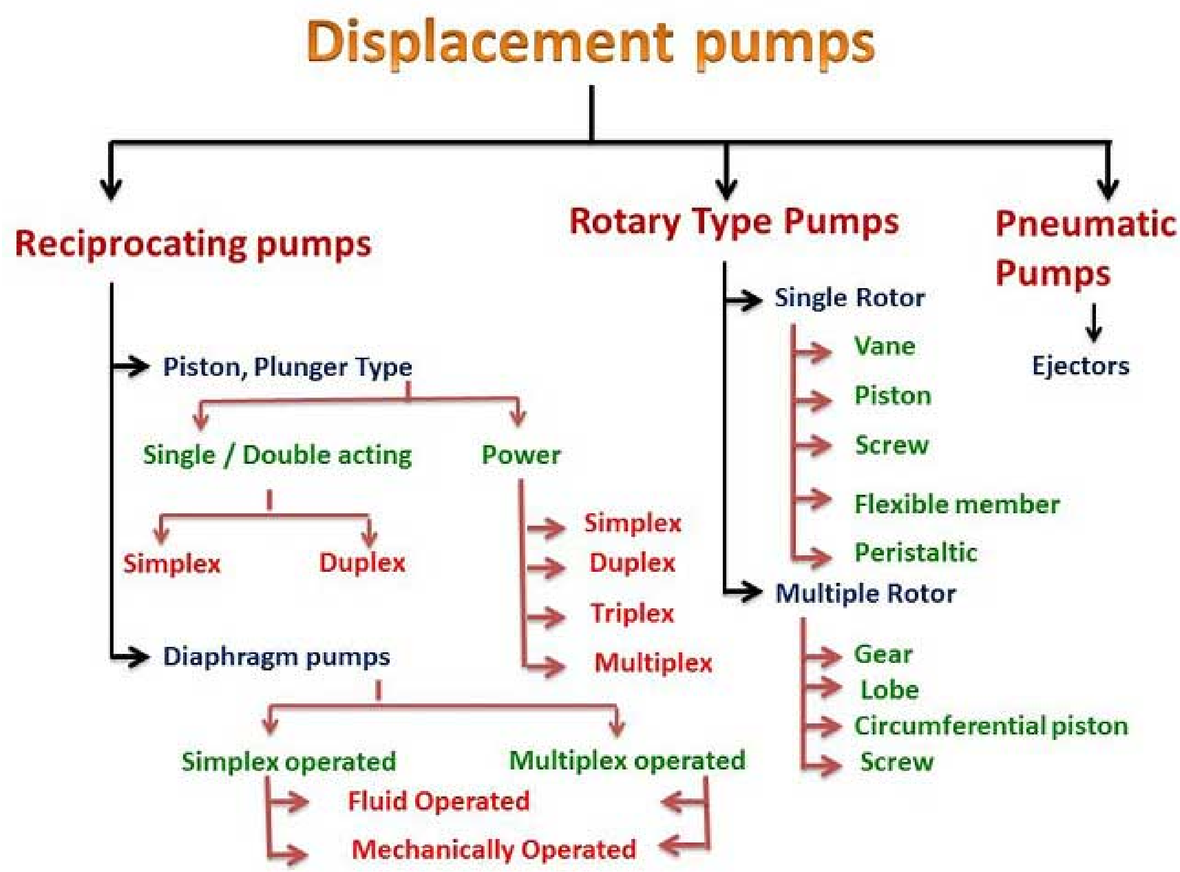
Submersible pumps are close-coupled pumps driven by a submersible motor and designed for submerged installation in a wet well. The motor is mounted below the bowl assembly and is directly coupled to the pump rotor shaft.

3. Horizontally mounted axial flow pumps

As the name suggests these pumps are just like the usual axial flow pumps but work in a horizontal plane.

Displacement Pumps

Positive displacement pumps, the moving element (piston, plunger, rotor, lobe, or gear) displaces the liquid from the pump casing (or cylinder) and, at the same time, raises the pressure of the liquid. So displacement pump does not develop pressure; it only produces a flow of fluid.



Positive displacement pumps are subdivided into three categories as follows:

A. Reciprocating pumps:

In a reciprocating pump, a piston or plunger moves up and down. During the suction stroke, the pump cylinder fills with fresh liquid, and the discharge stroke displaces it through a check valve into the discharge line.

Reciprocating pumps can develop very high pressures. Plunger, piston and diaphragm pumps come under these type of pumps.

1. Plunger / piston type pumps

The plunger contains the cross head, driven by a camshaft arrangement. The capacity of the pump can be adjusted by changing the stroke, the rotating speed of the pump, or both. The stroke of the pump is changed by the eccentric pin setting. These types of pumps are used for the application of sewage, sludge, scum, clarifier thickener underflow. It can be applied for transfer and for metering service. Such pumps are available in single- and multi cylinder models.

2. Diaphragm pumps

These type of pumps are quite versatile, handling a wide variety of fluids like food additives, chemicals, dry powders, slurries, pharmaceutical products, and wastewater etc. The advantages in diaphragm pumps is the absence of seals or packing, meaning they can be used in applications requiring zero leakage.

B. Rotary Type Pumps

The pump rotor of rotary pumps displaces the liquid either by rotating or by a rotating and orbiting motion. The rotary pump mechanisms consisting of a casing with closely fitted cams, lobes, or vanes, that provide a means for conveying a fluid. Vane, gear, and lobe pumps are positive displacement rotary pumps.

1. Rotary Lobe Pumps

Lobe pumps contains two elastomer-coated rotors that are driven by an integral gearbox and synchronized by timing gears. The rotors run without touching each other or the casing. The liquid is drawn through the inlet port into the pockets between the lobes and chamber walls. Because liquid cannot escape between the two rotors, it discharges in the direction of rotation of the outer lobes through the discharge nozzle.

2. Screw Pumps

Screw pumps are a special type of rotary positive displacement pump in which the flow through the pumping elements is truly axial. Screw pumps are high-volume, non-clog, atmospheric -head devices that can pump a variety of solids and debris in raw wastewater without screening. Screw pumps, however, have a practical limitation as to pumping head.

3. Progressive Cavity Pumps

A progressive cavity pump is designed specifically to transfer abrasive and viscous fluids with a high solid, fibre, and air content. A hard steel screw rotor rotates and orbits within an elastomer stator.

C. Pneumatic Pumps

Compressed air is used to move the liquid in pneumatic pumps. In pneumatic ejectors, compressed air displaces the liquid from a gravity-fed pressure vessel through a check valve into the discharge line in a series of surges spaced by the time required for the tank or receiver to fill again.

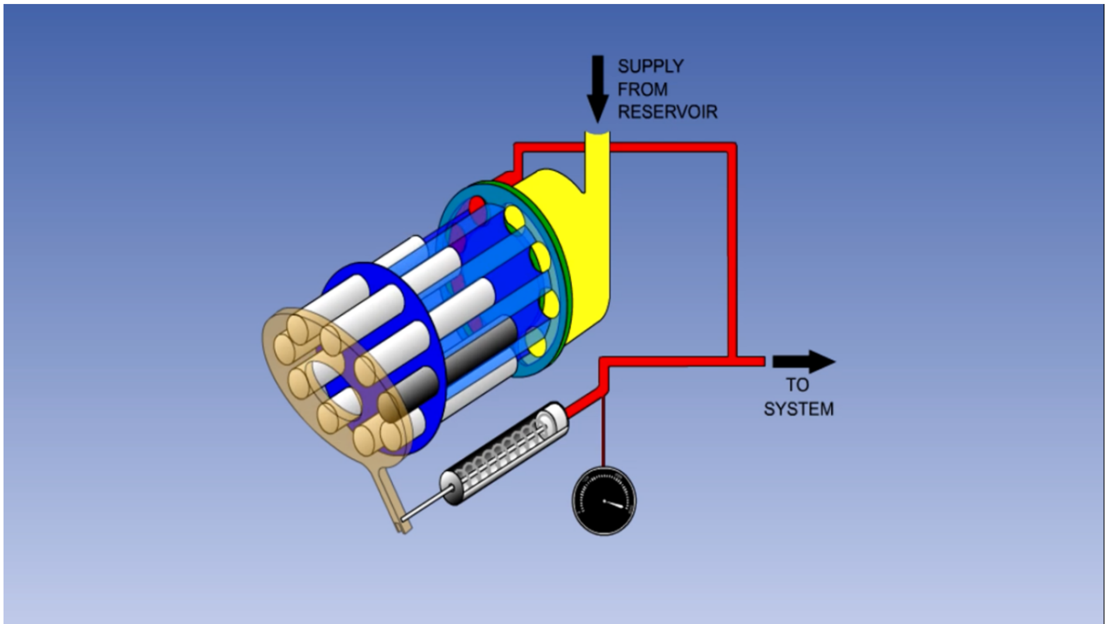
Pumps used in an Aircraft

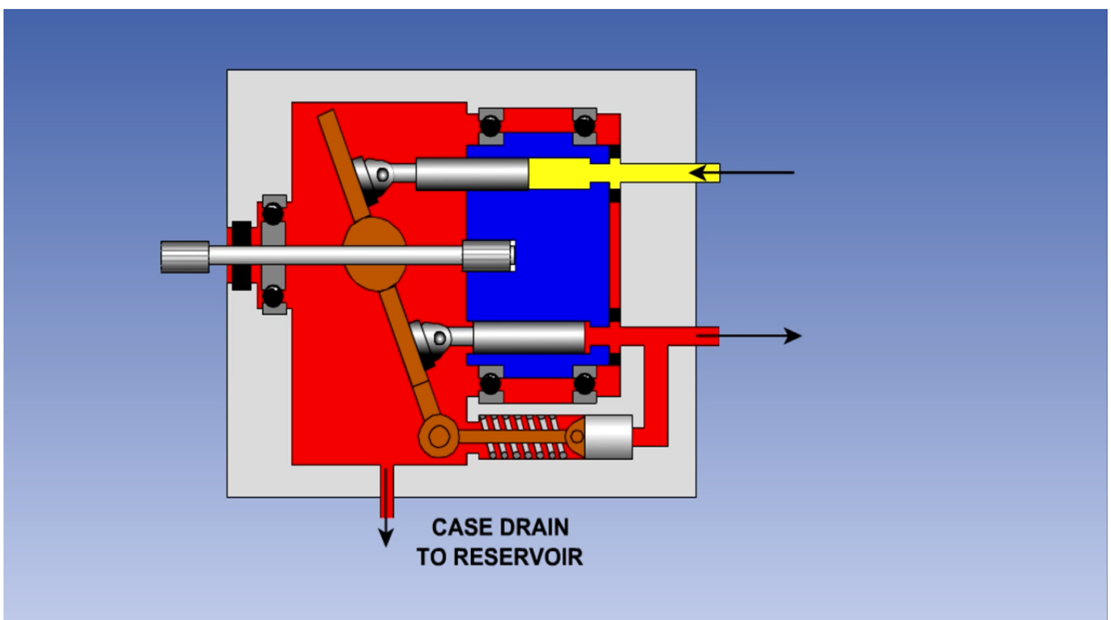
1. **Hand Pump**
2. **Engine Driven Pump (EDP)**
3. **Electric Motor Driven Pump (EMDP)**
4. **Pneumatic Pumps (Air Pump)**
5. **Ram Air Turbine (RAT)**
6. **Hydraulic Pumps (Using PTU)**

The Pneumatically operated pump, the RAT and the Hydraulic pumps are usually used to supply backup power to an engine driven pump, thus providing hydraulic system redundancy in the event of engine or EDP failure. This backup is usually used to operate primary flight controls and brakes. A hand pump may be the only source of hydraulic power in a small and light aircraft but in a large aircraft, hand pumps may be employed to allow ground servicing to take place without the need for engine running. This allows lines and joints to be pressure tested and cargo door to be operated. Hydraulic pumps are often accompanied by NRV (Non-Return Valves) and Relief Valves. The relief valve can be set to relieve at any required pressure. This is typically 10% above normal system pressure.

There are two types of powered pumps in common use; Constant delivery fixed volume type and constant pressure variable volume type. A typical example of Constant delivery fixed volume pump is spur gear displacement pump. One of the gears is driven by the power source and that gear in turn drives the other gear. As the gears rotate, fluid is carried around in the spaces between the teeth from the inlet to the outlet side of the pump. This type of pump gives a relatively large flow rate but its output pressure is quite low. This pump supplies fluid at a constant rate irrespective of demand. This pump needs a relief valve to return the fluid to the reservoir when the actuators have reached the end of their travels and the system is not operating. In order to prevent the relief valve from constantly cutting in and out, it is also required that such a system possess an accumulator.
The constant pressure variable volume (or variable displacement) type pump supplies a variable volume and can control its own pressure. This pump is a common sight in a modern aircraft whose systems operate around 3000 or 4000 psi pressures.

Variable displacement Constant pressure pump (VDCP)





Components of a VDCP Pump

1. **Kidney plate**
   A round plate with kidney shaped cut outs in it. Fluid from the reservoir (which circulates through the whole of aircraft hydraulic system) enters through one of the cut-outs and the pressurized fluid exits through the other.

2. **Cylinder block**
   This is a solid cylinder with several cylindrical slots in it which house the pistons that reciprocate up and down while also rotating with the power source and shaft. They are primarily responsible for the pumping and suction effect. There is direct metal to metal contact between rotating cylinder block and the kidney plate. This contact is lubricated by hydraulic fluid art system pressure.

3. **Pistons**

   The pistons fit inside the grooves made for them on the cylindrical block. All of the pistons are connected by shoes to the non rotating swash plate (yoke). Lubrication in this is also by hydraulic fluid at system pressure.

4. **Swash plate**

   The tilting of the swash plate which connects the pistons through shoes is varied with the help of a control piston.

5. **Control piston**

   The control piston has pump outlet pressure on one side of it and a spring on the other. With the pump stationary, there will be no hydraulic pressure, so the spring will push the control piston fully to the right and the swash plate angle will be maximum.

6. **Case drain**

   The entire assembly is housed in hydraulic fluid, cooling the pump before it is returned to the reservoir by an independent pipeline. (case drain fluid) The condition of the case drain filters is a good indication of the health of the pump.

Working principle

As the pump starts to rotate, the pistons will ride up and down the angle of the swash plate moving in and out of the cylinder block. The pistons move out as they pass through the inlet kidney plate slot sucking fluid inside and move inwards as they pass through the outlet slot forcing fluid outside at a pressure. As the pressure builds up, the control piston moves to the left reducing the swash plate angle and therefore the pump output. When normal operating pressure is reached, when no services are being operated, the swash plate is almost vertical and the piston movement will be almost zero with a small flow through the pump for cooling and lubrication. It returns to the reservoir through the drain line. If a service is operated, the system pressure will fall, the spring will push the control piston to the right, increasing the swash plate angle and hence the piston stroke. Pump output will increase to maintain the required pressure. When the service reaches its required position, the output pressure will again rise and swash plate will return to its no load position. Since the case drain fluid becomes hot, it is cooled through a heat exchanger (fuel is warmed) before returning to the reservoir.

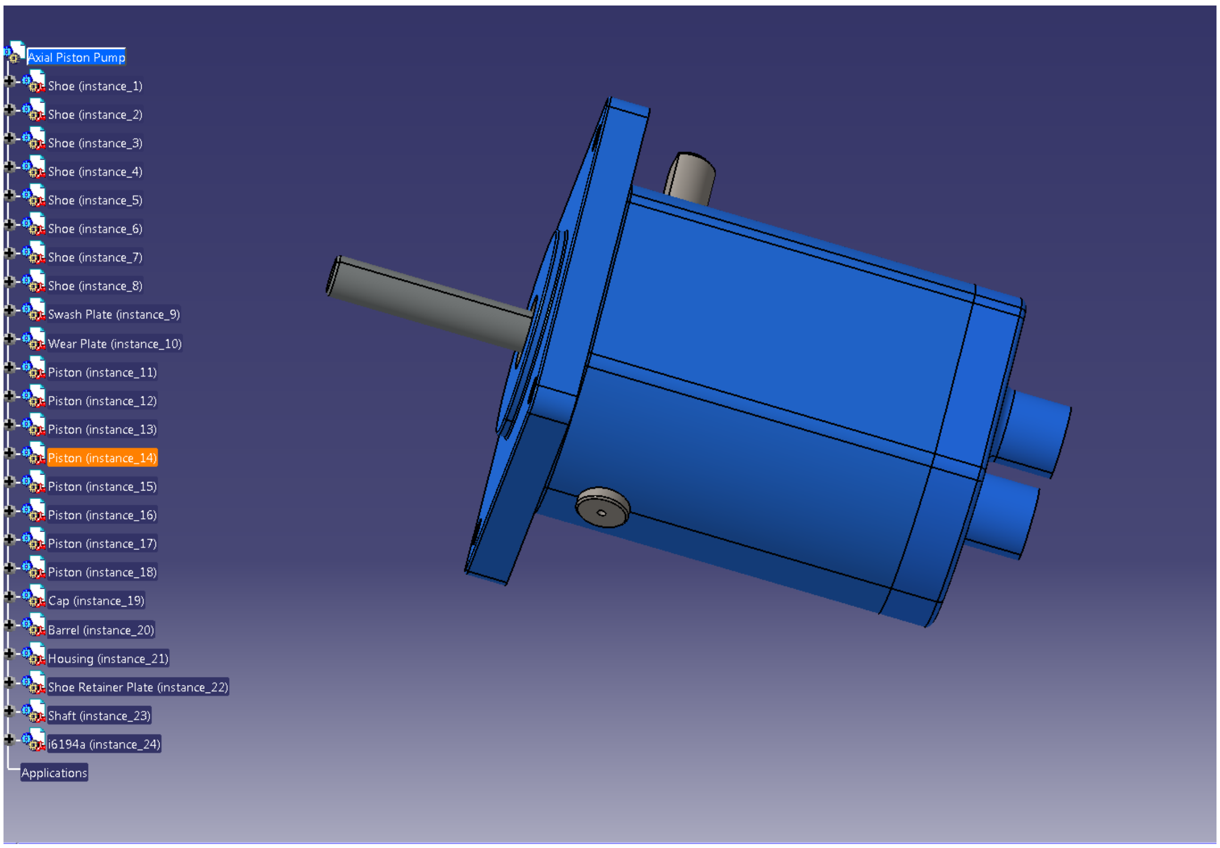
Our project focuses on the main hydraulic pump, whose specifications are as follows. The main pump (2 in numbers) are connected directly to the AMAGB (Aircraft Mounted Accessory Gear Box)

Type:	VDCP (Variable Displacement Constant Pressure)
Speed:	6000RPM
Pressure:	280 Bar
Rated flow:	110 - 115 LPM
Suction pressure:	5.5 Bar

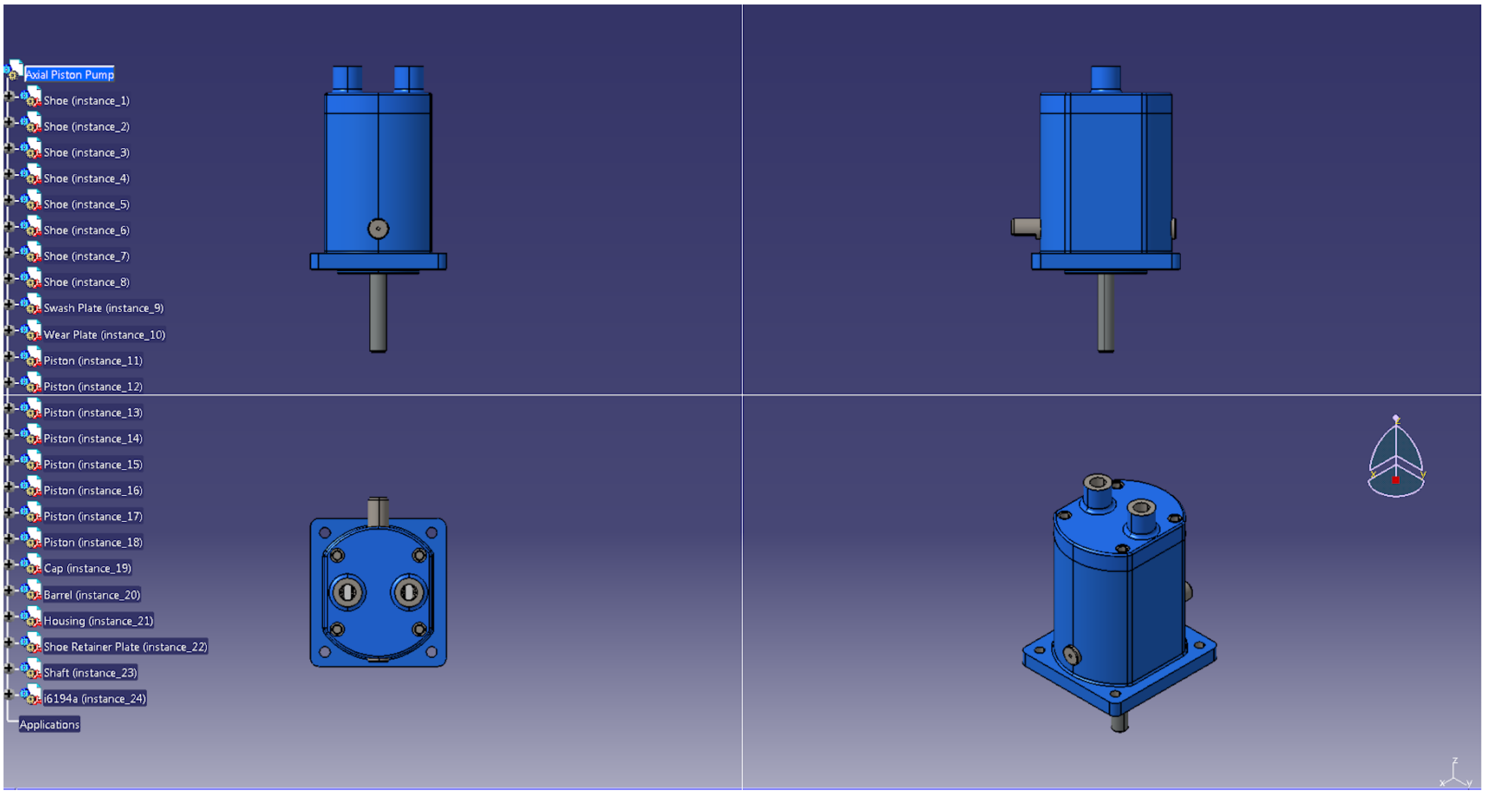
Design

CAD of Pump Assembly

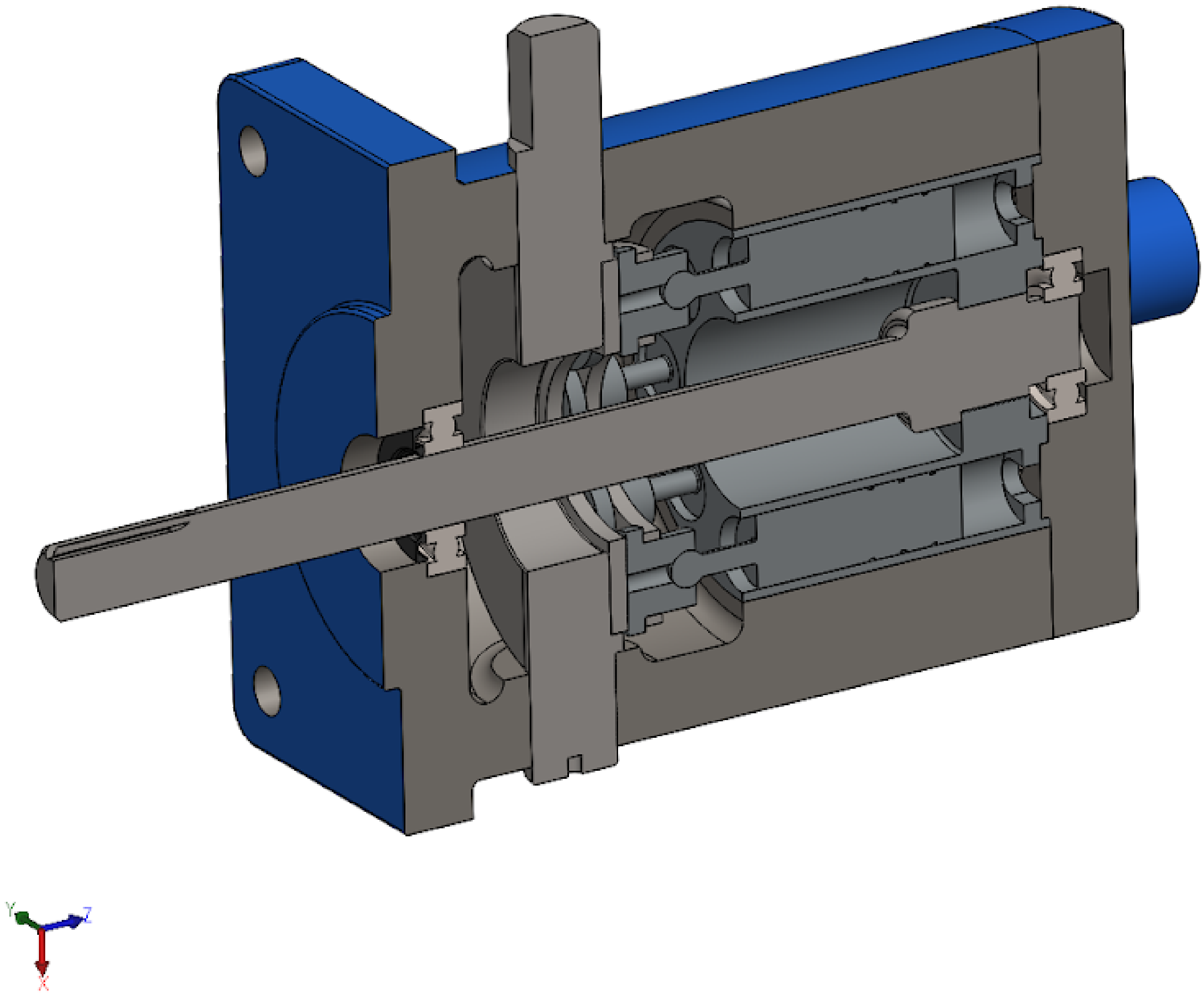
Isometric Projection of Pump Assembly



First angle projection of Pump assembly



Sectional View of the Pump Assembly



Problem Methodology

The following points describe the approach followed for achieving the aim of the internship.

Pre-Modelling

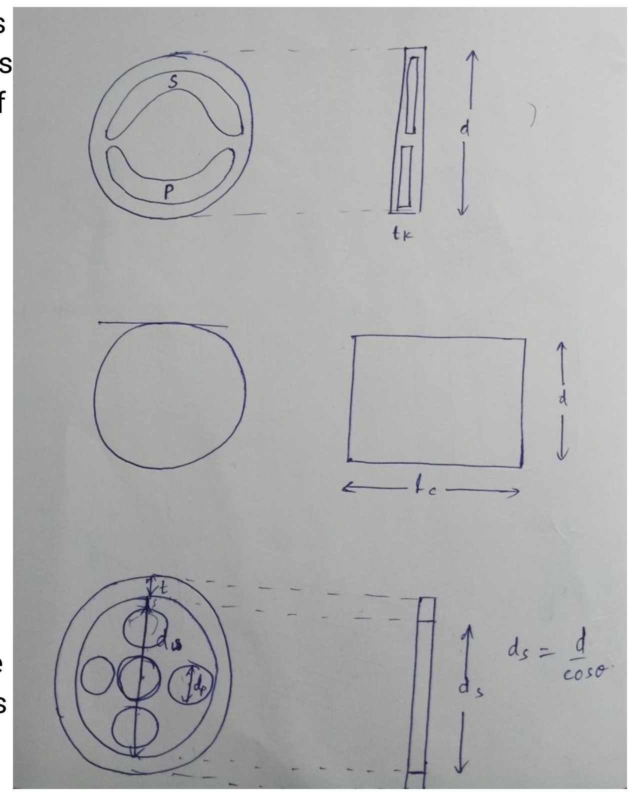
1. We studied the hydraulic system of the Tejas aircraft and understood the role of hydraulic pumps (main pumps and other pumps) in regulating fluid flow.

2. We collected necessary data on the main pump. The main pump is a VDCP pump. We obtained the required numbers (the maximum suction pressure, the maximum tolerable pressure of the hydraulic pump, the fluid flow rate through the pressure and suction ports, etc.)

3. Using the above data and adhering to the specifications we used flow rate equation: Volumetric flow rate = cross sectional area* velocity of fluid to calculate the areas of cross section for the suction and pressure ports.

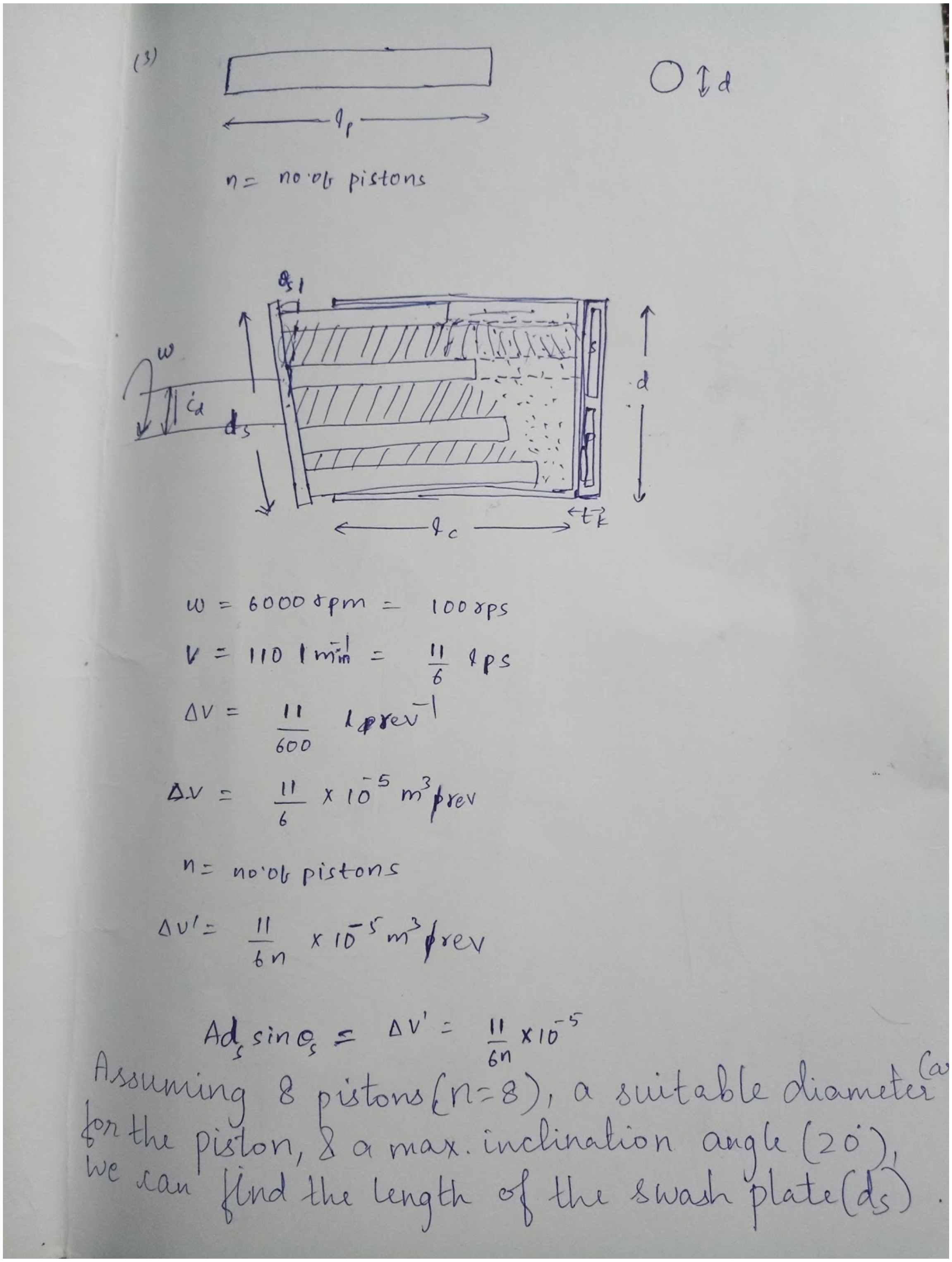
4. We decided on the maximum dimensions of the components of the VDCP pump based on the CAD model provided to us of the pump and AMAGB. We designed the components of the pump setting the dimensions of the casing as upper limits for our pump design. Using data from our flow rate calculations and the CAD file from DLE, we were able to decide on the number of pistons, their individual areas, volumes, total displacements and other related parameters.

5. We decided the maximum swash plate turn angle. This was to be selected in such a manner as to not force the pistons to have a component of acceleration which was not along the axis parallel to the cylindrical block.



*The picture shows hand drawings of several parts of the pump

Picture shows several hand calculations helpful to evaluate the volume of the barrel needed, eventually determining the size of the pump.


(3)

l_p ; d

n = no. of pistons

$\omega = 6000\ rpm = 100\ rps$

$V = 110\ l\,min^{-1} = \frac{11}{6}\ lps$

$\Delta V = \frac{11}{600}\ l\,prev^{-1}$

$\Delta V = \frac{11}{6} \times 10^{-5}\ m^3\,prev$

n = no. of pistons

$\Delta V' = \frac{11}{6n} \times 10^{-5}\ m^3\,prev$

$A d_s \sin\theta_s = \Delta V' = \frac{11}{6n} \times 10^{-5}$

Assuming 8 pistons (n=8), a suitable diameter (ca for the piston, & a max. inclination angle (20°), we can find the length of the swash plate (d_s).

Modelling

6. After this we built a prototype CATIA model but were at an impasse when it came to the selection of an appropriate joint connecting the pistons to the swash plate that would allow the bending of the swash plate independent of the revolution of the pistons. This problem was solved by using ball and socket joint between the ball (on the piston) and a shoe (socket) attached to the swash plate which permitted this independent motion. After this the model could be built successfully.

Simulation

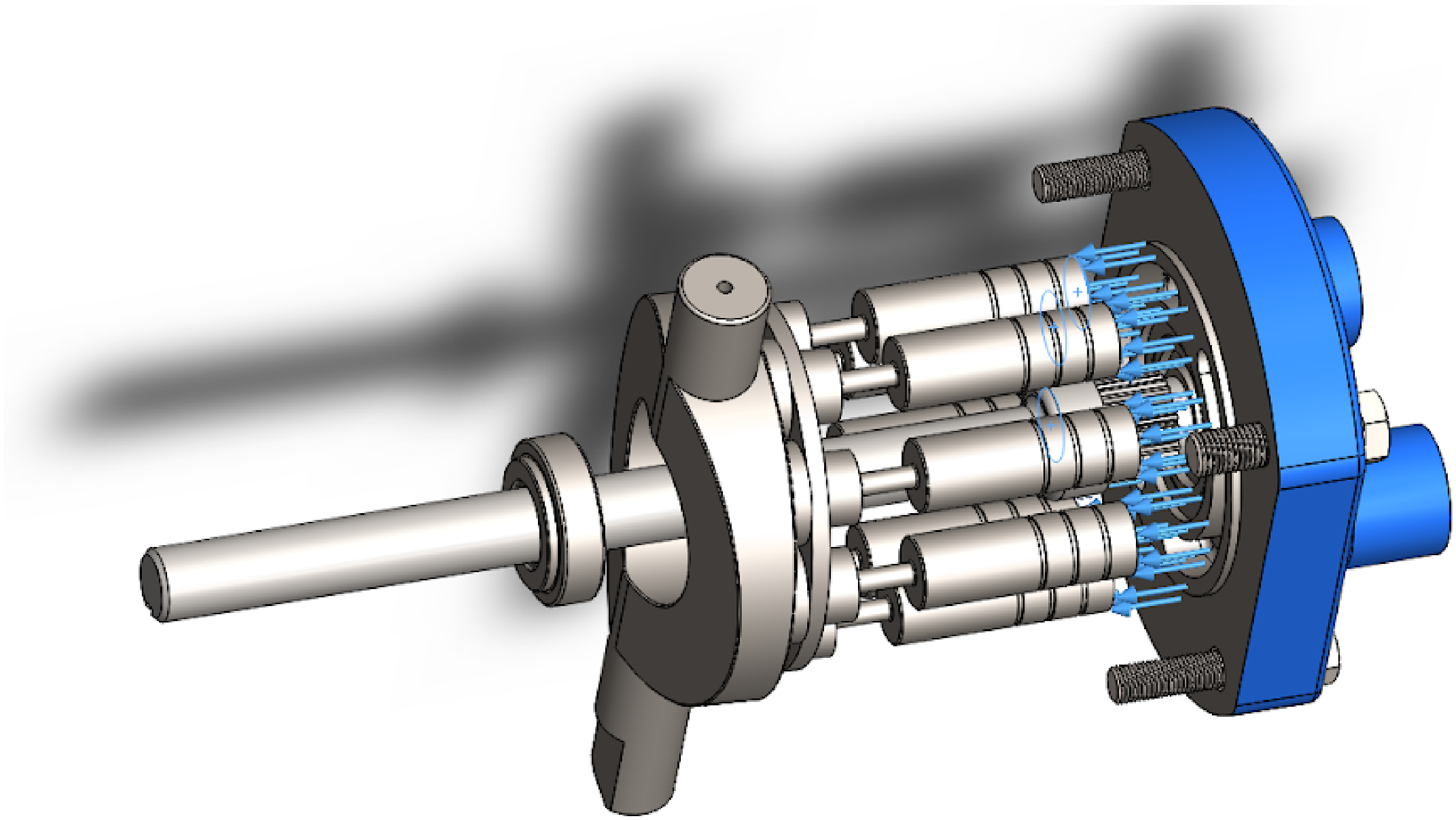
7. We have come to the conclusion that simulation is necessary for
    a) Material Selection
    b) Testing the feasibility of the design
    c) Determining the minimum factor of safety of every component

8. For this purpose we chose ANSYS but the software failed when it had to simulate the complex assembly geometry under stipulated condition. Hence we have divided the simulation into two stages. First stage would be to model the assembly on Solidworks and run a simulation under the working conditions of the pump. The second stage was to model the part which took maximum of the load on ANSYS.

9. As planned, the assembly modelling in solid works is produced below although we were not successful in getting the simulation results on Solidworks due to limitation of computation power.

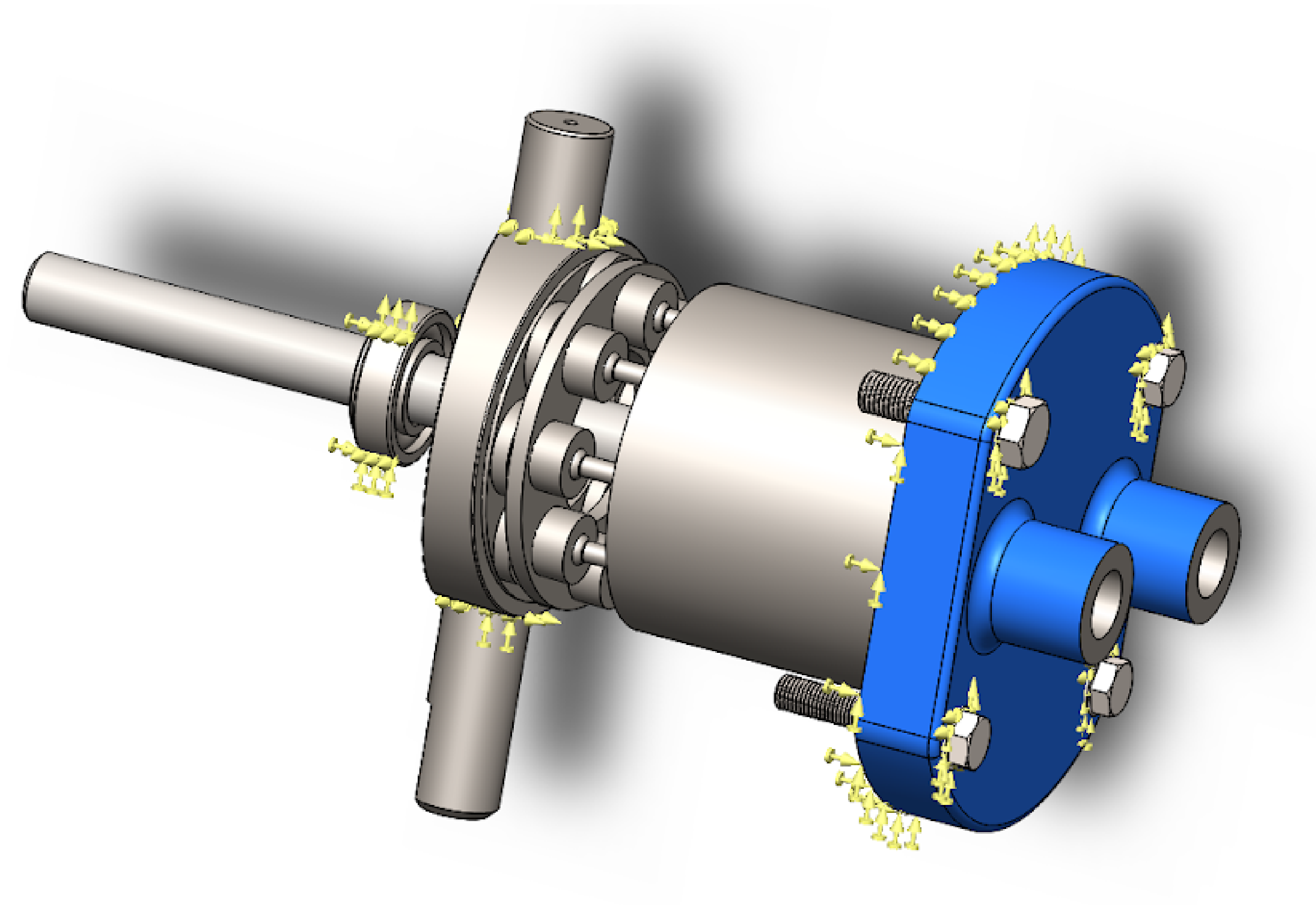
10. However, the modelling and simulation of Barrel were successfully performed on ANSYS and the results are produced as follows.

Pressure and Fluid Flow



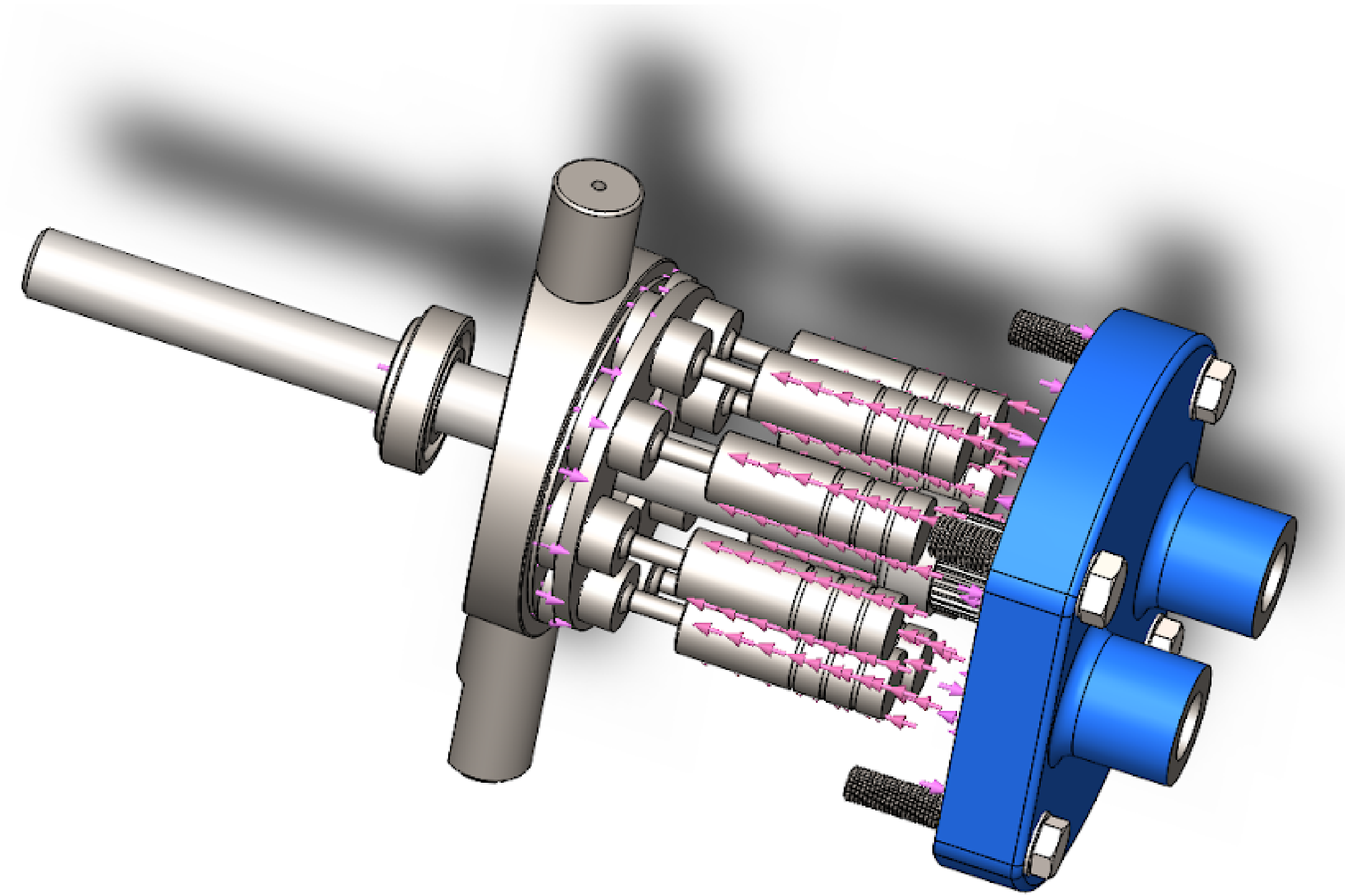
- In the above picture, the blue arrows indicate the direction of fluid flow into the pump through the suction port of the kidney plate and out of the pump through the pressure port.
- At any instant of time 4 pistons have 280 bar pressure on them while the rest of the 4 pistons have 5 bar pressure on them normal to their surfaces as indicated.
- The simulation has been carried out for the worst case possible, ie; 280 bar pressure everywhere. (At all locations indicated by the blue arrows)

Fixed Supports



- In the above picture, the yellow arrows indicate the fixed supports.
- They'll have stress concentrations on all the joints.

Frictionless surfaces

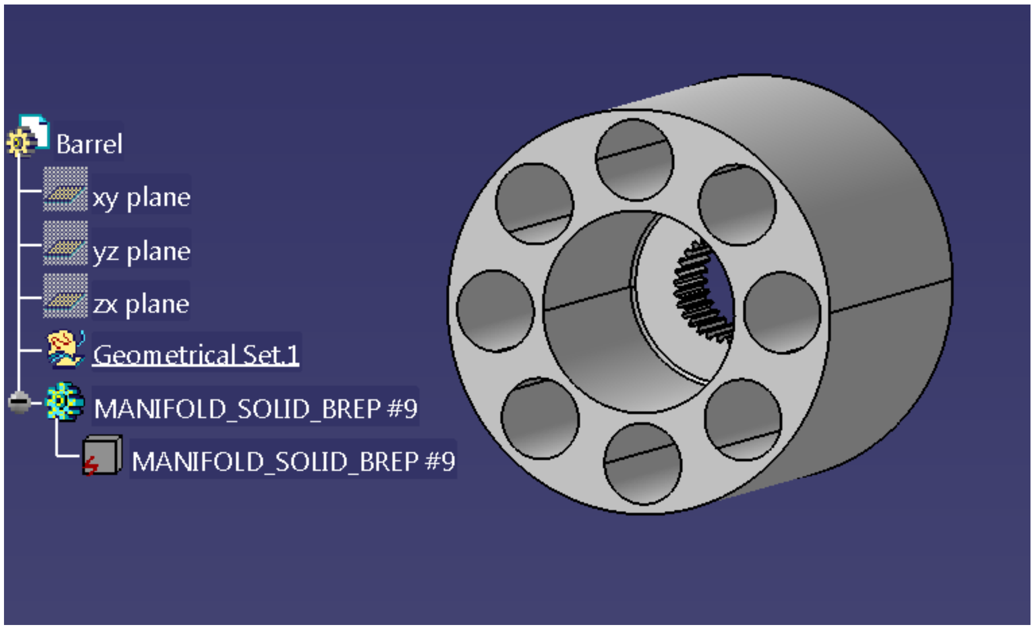


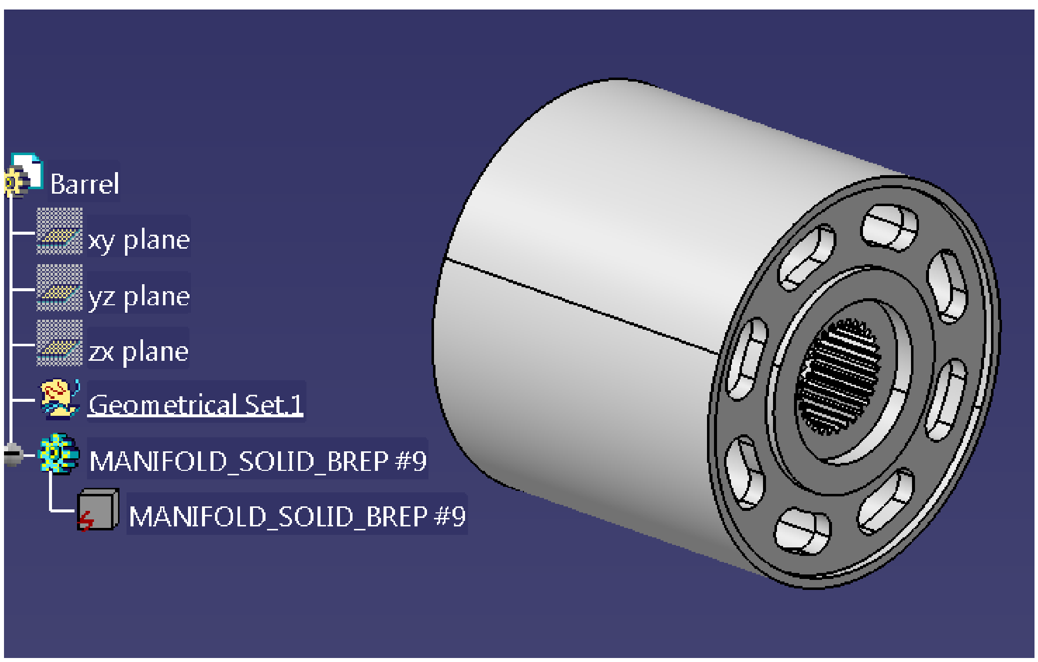
- In the above picture, the pink arrows indicate frictionless contacts.
- Providing this constraint facilitates the motion of piston inside Barrel, along the axis.

Barrel

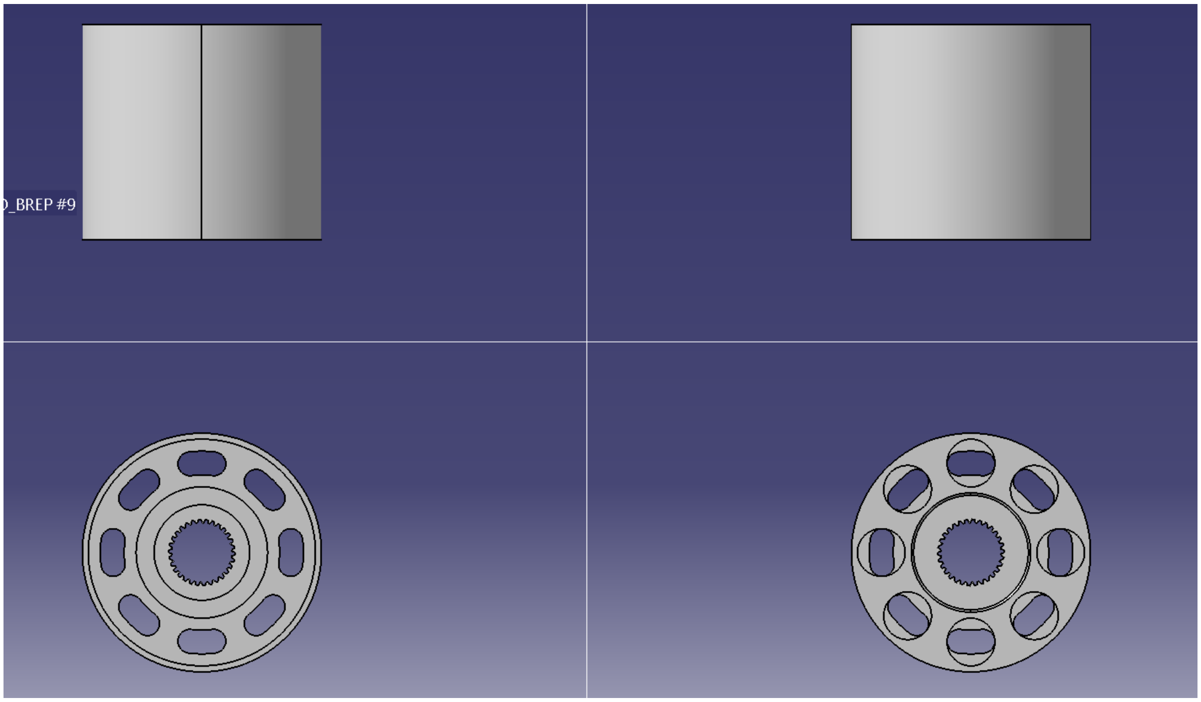
CAD Model of Barrel

Isometric Projections of Barrel





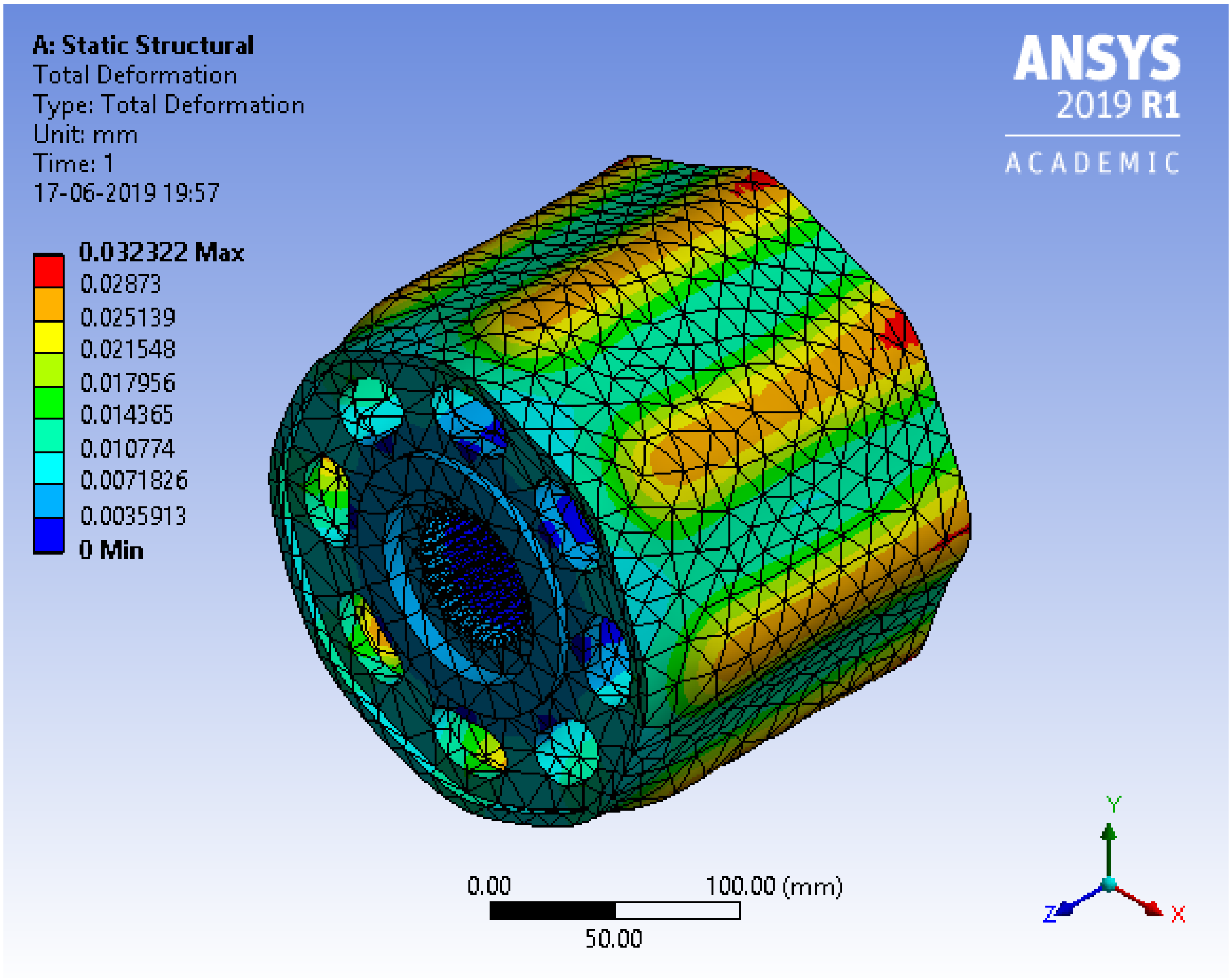
First angle projection of Barrel



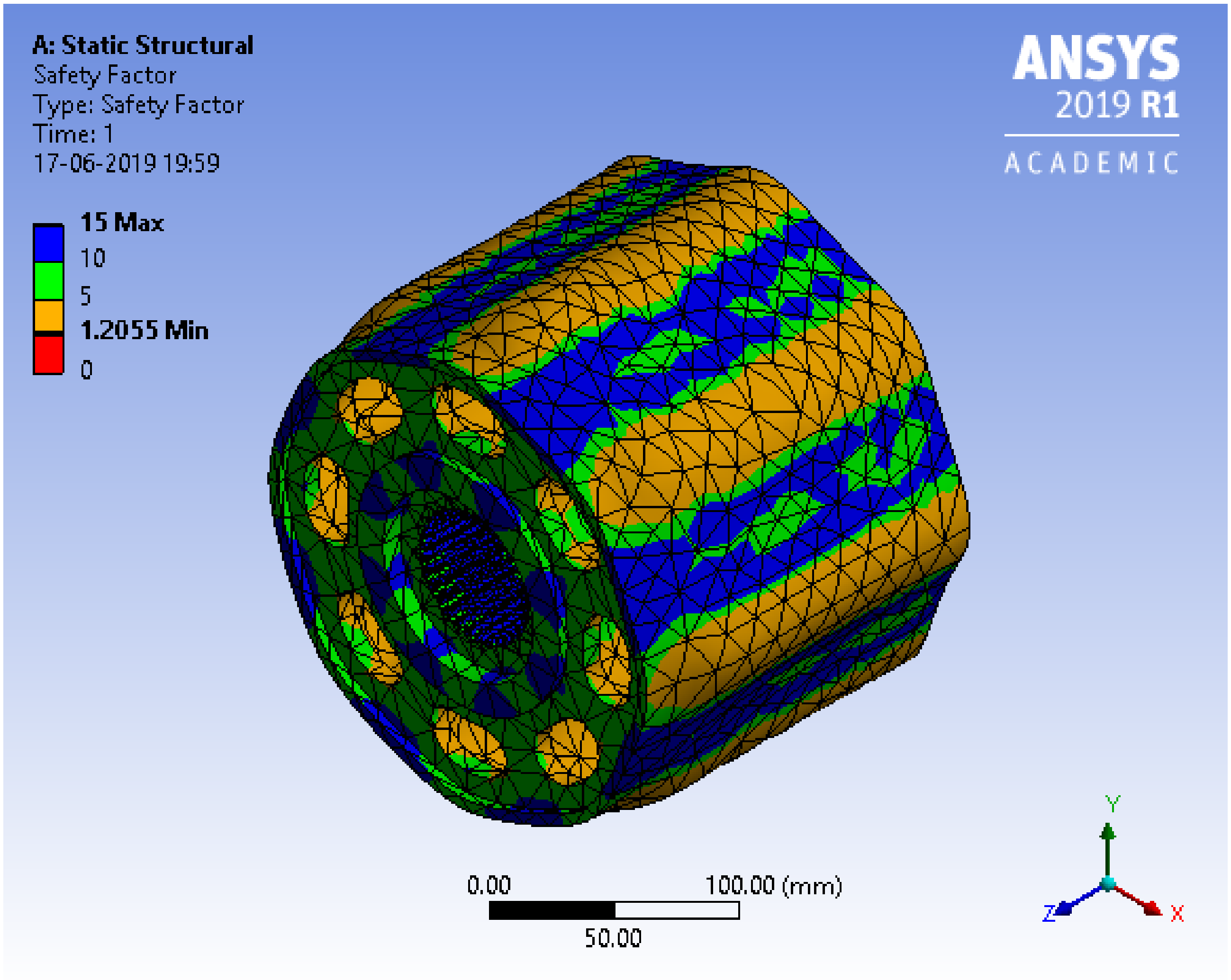
The barrel is one of the crucial components on the pump. It houses the pistons, which form the necessary compression to pressurize the liquid, and connects it to the kidney plate, which houses the inlet and outlet for the liquid. The barrel is under constant revolutions, owing to the shaft which slots into the barrel.

Recommended Manufacturing Process for Barrel

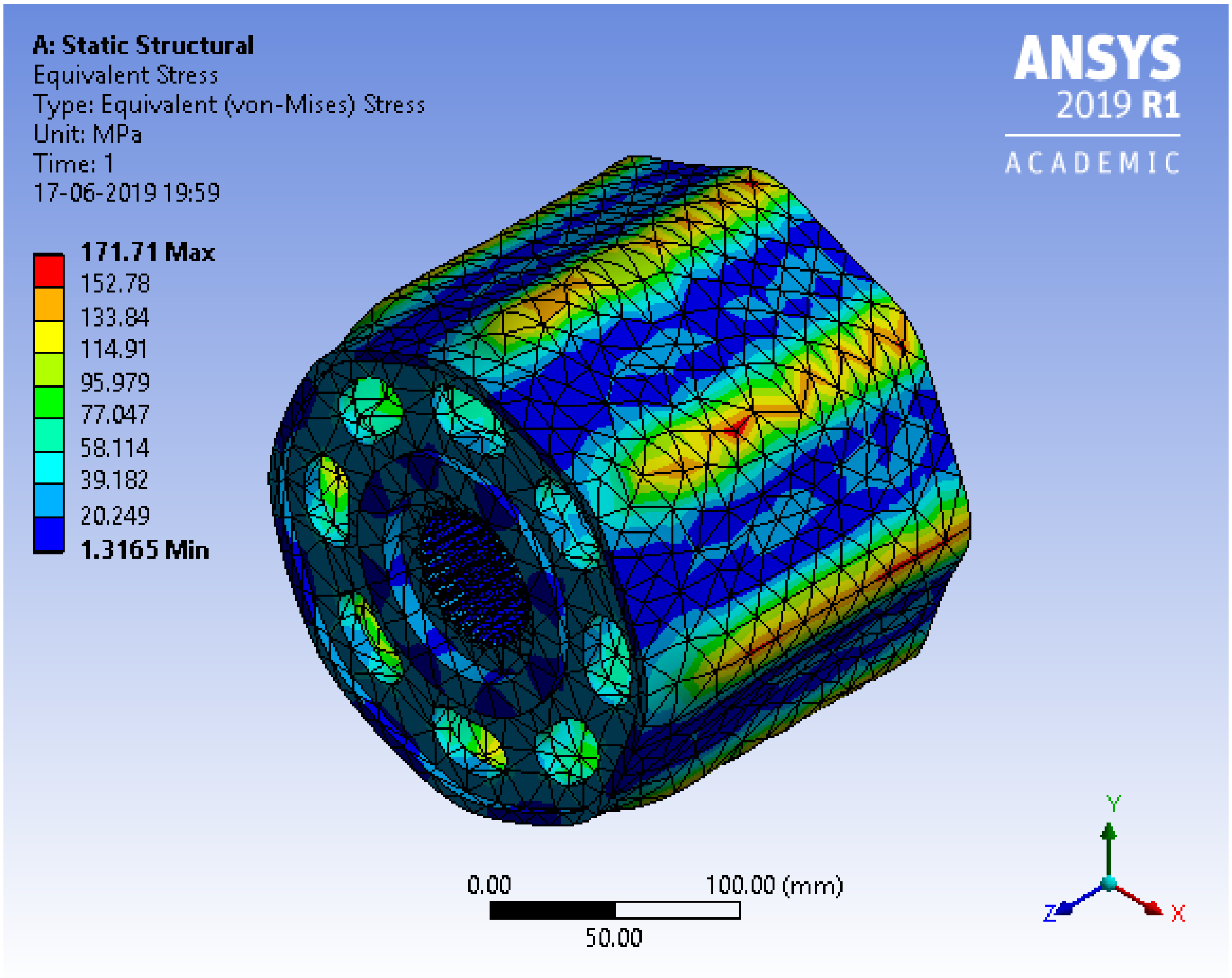
1. From the simulation, stainless steel was found out to be the best suited material for the construction of the barrel.
2. A part of the raw material billet is first cut to approximate desired length.
3. The job is then turned on a lathe (or CNC lathe), to bring it to the required external diameter.
4. Facing (with the help of a lathe) is used to bring it down to the precise length required.
5. With the help of a precision Milling machine (or a CNC miller), the elliptical grooves on the outlet-side of the barrel are machined.
6. Then, a drilling machine (or a CNC equivalent) will be used to make the holes for both the shaft (which is followed by several steps of boring), and the various pistons.
7. The locking mechanism of the shaft is then carved using the appropriate internal threading tool.
8. All the surfaces undergo necessary finishing processes to adhere to the specifications.



Total Deformation Analysis using ANSYS on the Barrel



Safety Factor Analysis using ANSYS on the Barrel

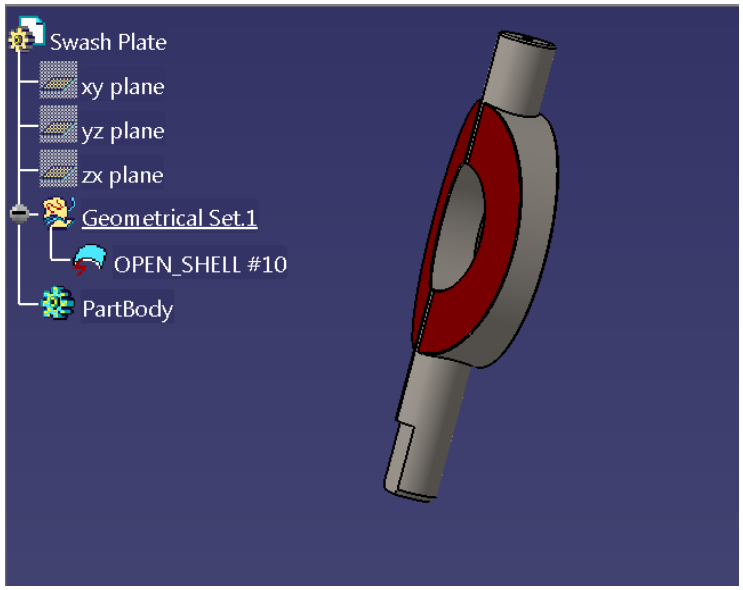


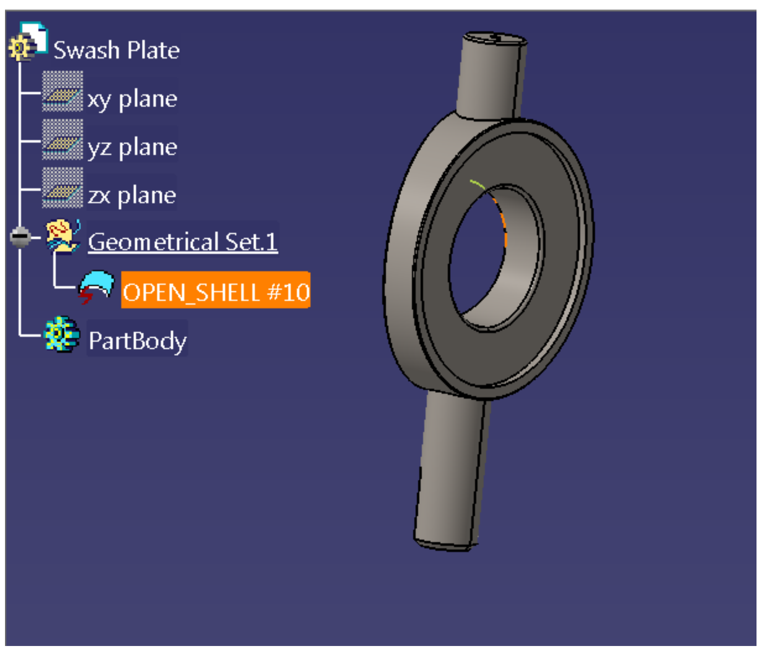
Equivalent Stress Analysis using ANSYS on the Barrel

SWASH PLATE

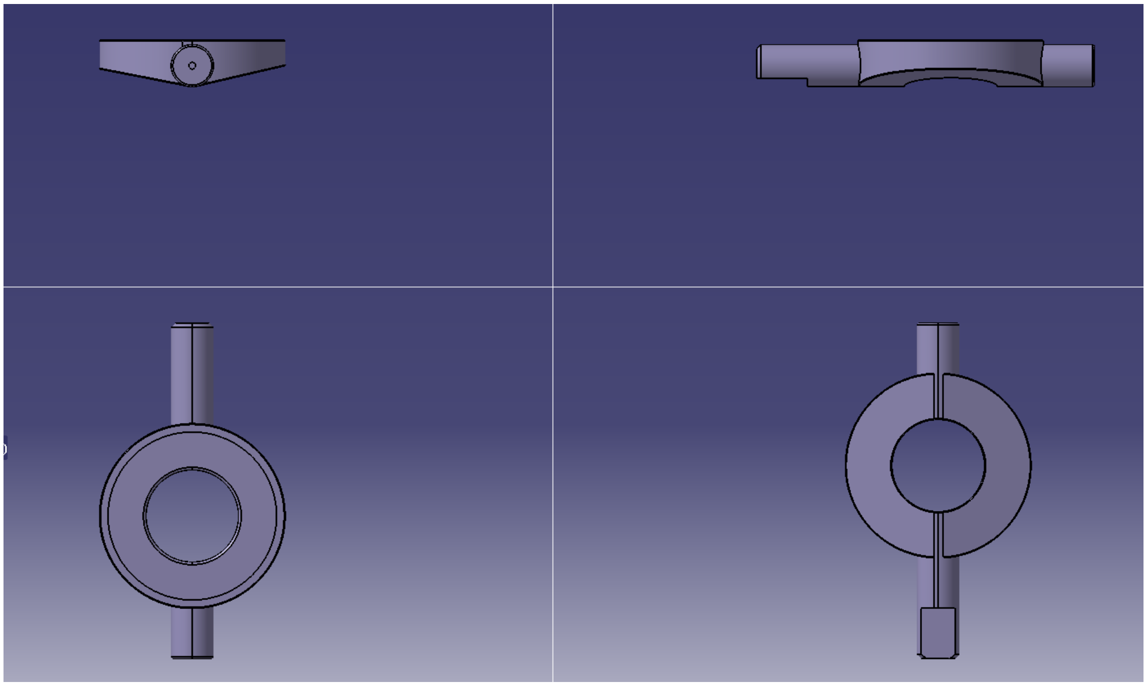
CAD Model of Swash Plate

Isometric projection of Swash Plate





First angle projection of Swash Plate



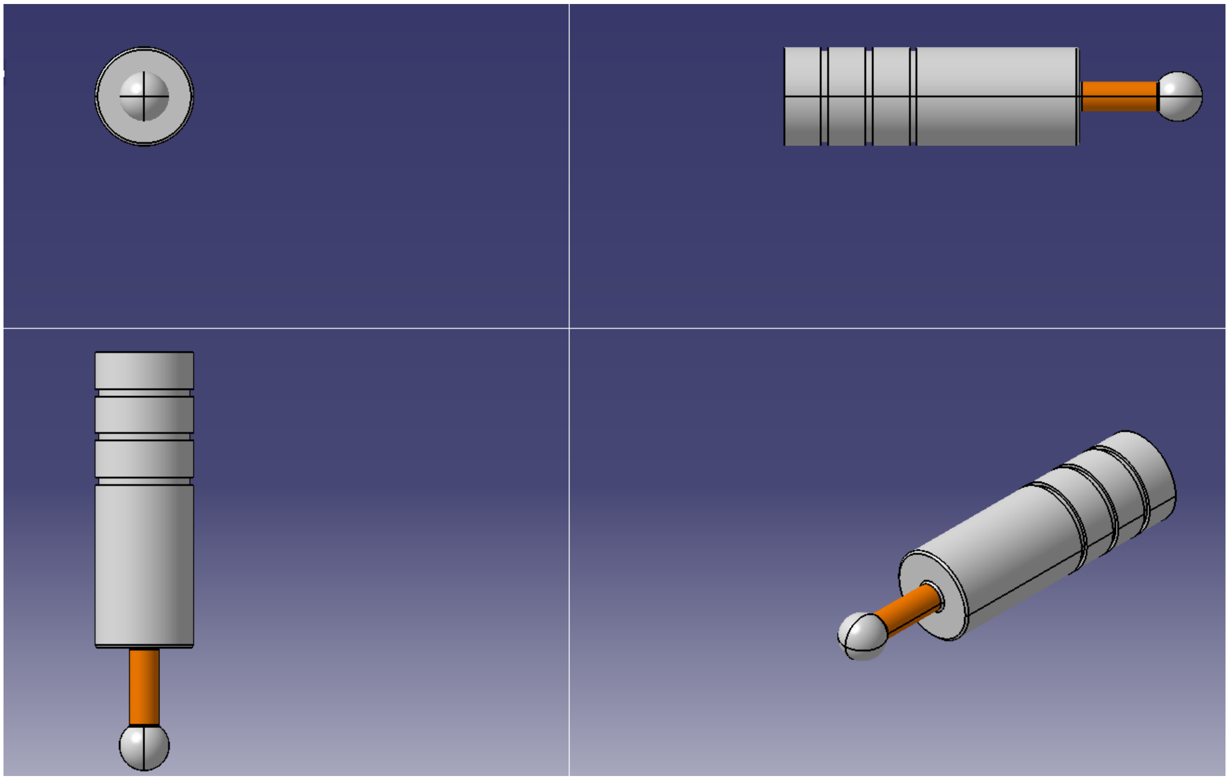
The Swash plate is plays a huge role in guiding the path for the pistons, thereby producing the necessary compression and hence pressurizing the liquid. It in itself is stationary, resting on a ball bearing present on the shaft. However, it can tilt about its axis as a method of feedback from the pressure valve.

Recommended Manufacturing Process for Swash Plate

1. A part of the raw material billet (of a diameter which is at least the outer diameter of the donut part of the swash plate), and cut to a length slightly larger than the length of the swash plate.
2. Turning is carried on a lathe (or CNC lathe), to make both the end cylinders on the swash plate.
3. Facing (with the help of a lathe) is used to bring it down to the precise length required.
4. With the help of a CNC miller, the piston-side of the swash plate is machined, following which the shaft hole is made.
5. Then, after flipping the side, the oblique faces of the swash plate are finished.
6. The flat surface on the end cylinder is then milled.
7. All the surfaces undergo necessary finishing processes to adhere to the specifications.

PISTON

CAD Model of Piston



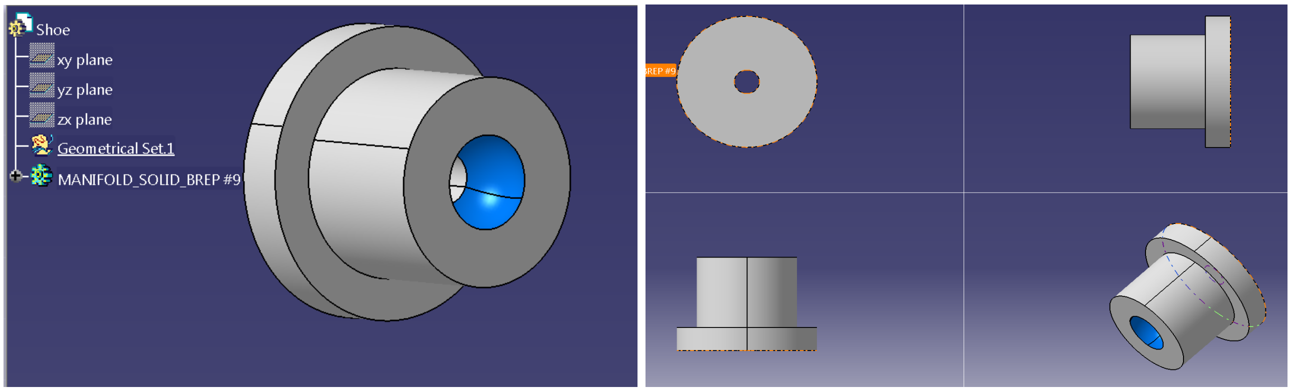
The piston is also a crucial component whose individual to-and-fro oscillations (which are guided by the swash plate) help in pressurizing the liquid. Its spherical end compensates for the tilt that can be achieved by the swash plate, which makes all stresses in the cylindrical part nearly one-dimensional, thereby eliminating destructive lateral stresses.

Recommended Manufacturing Process for Piston

1. To achieve the greater amounts of precision required for this purpose, the whole thing is manufactured using precision casting processes. This helps to mass-manufacture, as the pistons are more in number.
2. All the surfaces undergo necessary finishing processes to adhere to the specifications using lathe and other finishing processes.

Shoe

CAD Model of Shoe



It allows the piston's axis to stay parallel to that of the cylindrical block's axis while allowing the tilting of the swash plate to take place. The shoe ensures a strong yet flexible joint between the pistons and the swash plate with two degrees of freedom.

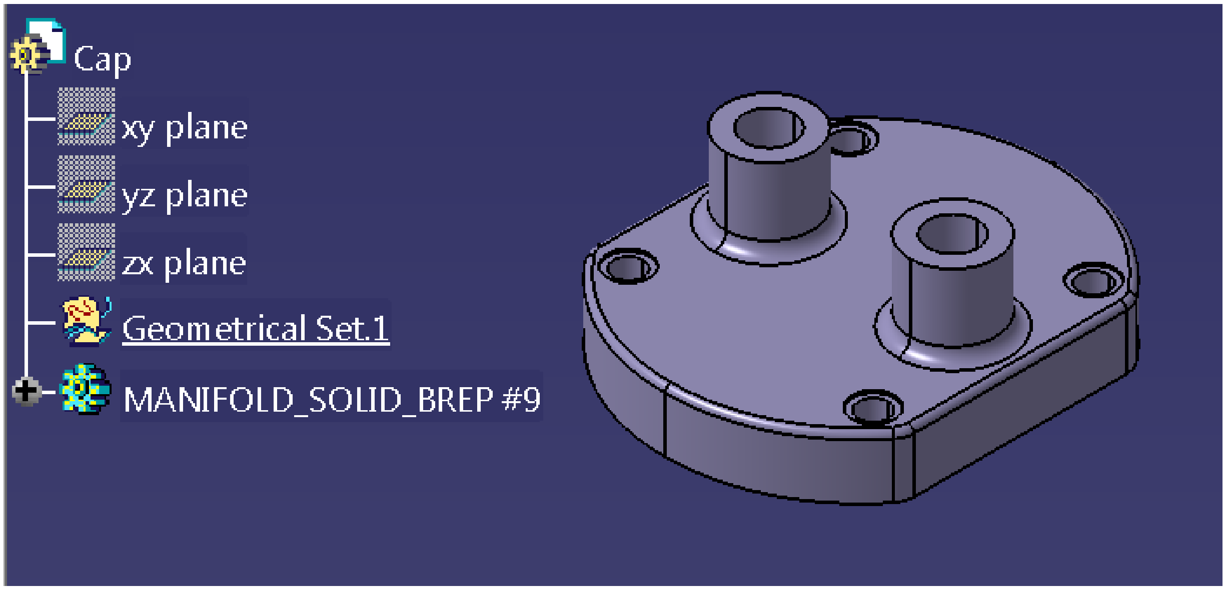
Recommended Manufacturing Process for Shoe

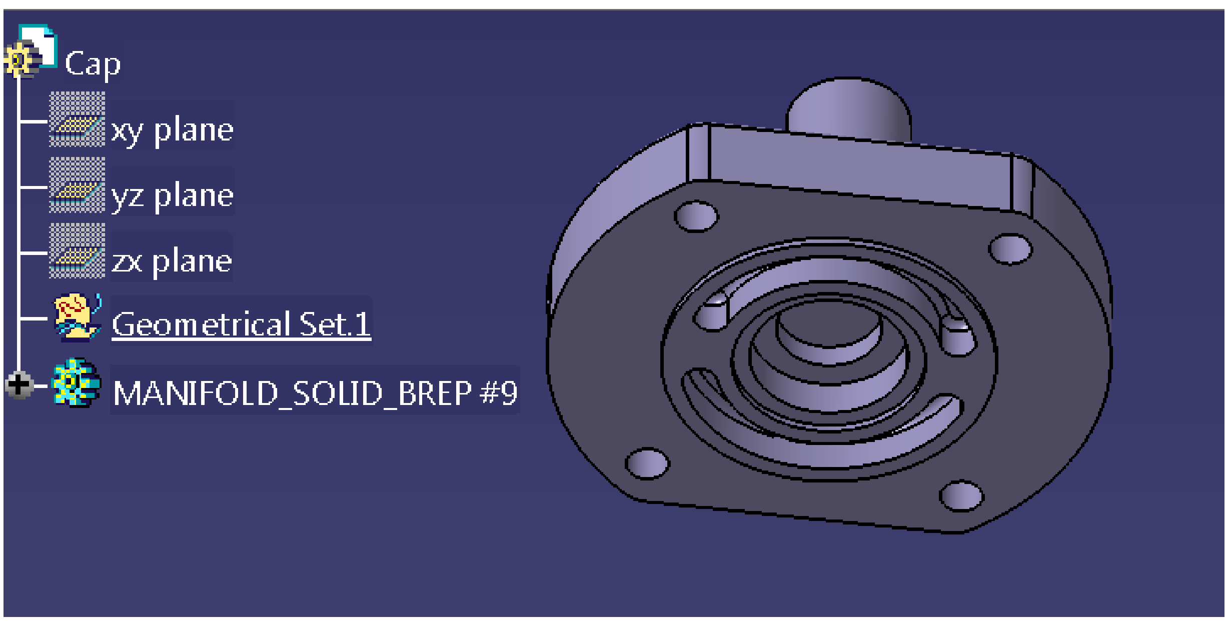
1. Due to the difficulty in manufacturing a hemispherical cavity, the shoe is best produced by casting.
2. The whole surface (inside and outside) is polished so that it adheres to the required specifications.

COVER

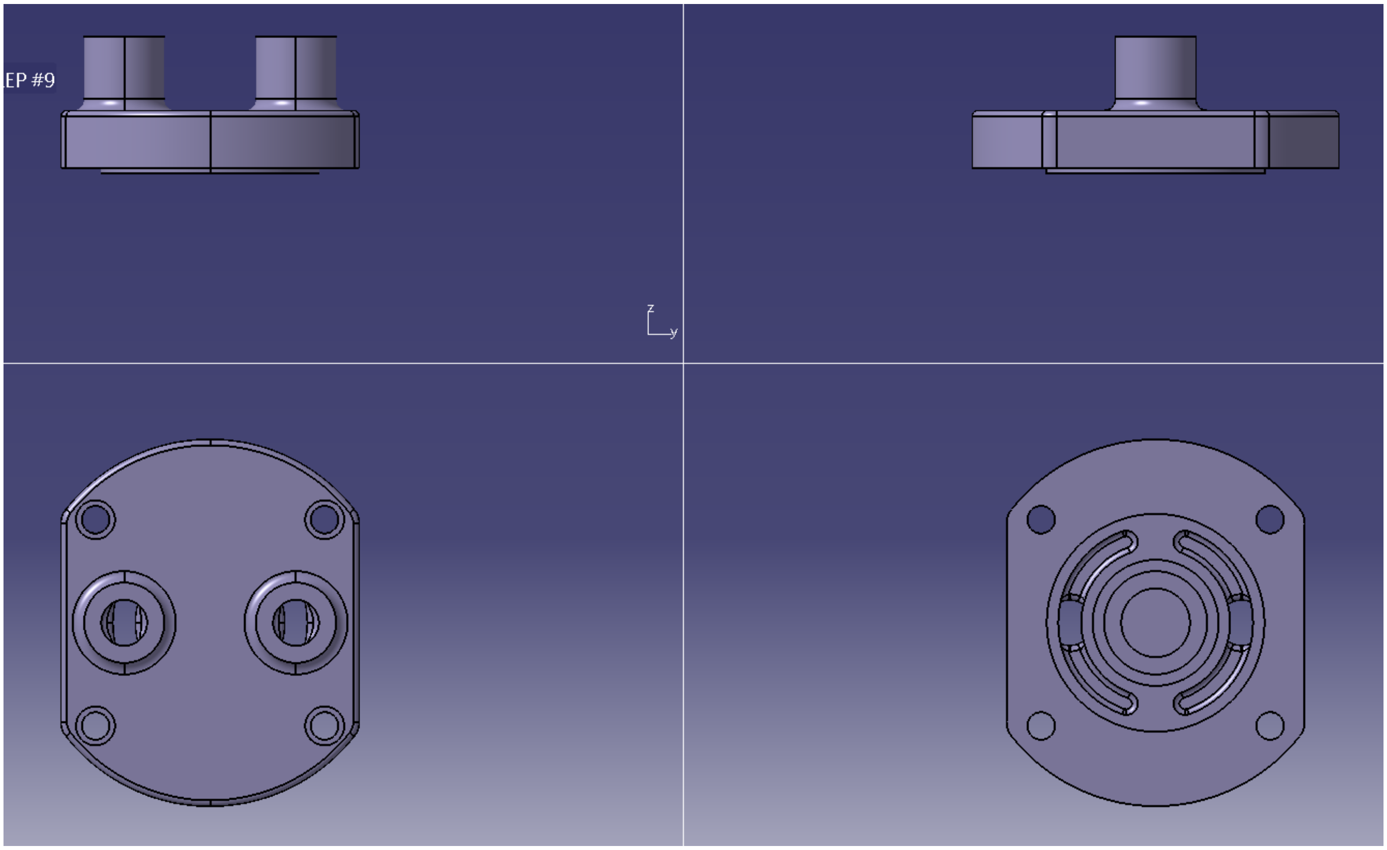
CAD Model of Cover

Isometric Projections of Cover





First angle projection of Cover



It houses the inlet and outlet pipes , with kidney plate at the back.

Recommended Manufacturing Process for Cover

1. The whole of the part is machined on a vertical CNC milling machine. The cylindrical projections and the grooves in them can be made using the same vertical CNC machine.
2. The required holes can be drilled using a drilling machine with tools of suitable diameters. This function can also be performed on a CNC drilling machine (vertical).

Drawbacks

This model covers the static structural analysis of the mechanism of the pump; that is, this analysis determines whether the structure of the pump with the selected materials can withstand the stipulated static external loads. For example we have only taken into account the pressures, rotation, weight, and the modes of connection between components (joints).

This analysis does not cover

- Flow dynamics on the pump
- Thermal response of this design
- Limits of dimensions and tolerances of various parts weren't stated explicitly
- Manufacturing drawings weren't stressed upon
- Feedback and emergency systems weren't touched upon
- Jamming and interferences studies (especially between swash plate and pistons) weren't carried out

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Scope for future improvements

- Carrying out CFD analyses to further improve on the dynamic response of the pump
- Decide on the limits and tolerances through further studies and tests
- System can be subjected to tests for the given temperature range
- Developing prototypes and subjecting those to real time tests to ascertain real world parameters like wear and fatigue.
- Improving on materials used to specifically suit the purpose

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Conclusions: -

1. With this internship, knowledge on industrial practice that too for aircraft build has been gained
2. The assembly sequence of a fighter aircraft has been learned
3. The basic requirement for designing a hydraulic pump has been understood
4. A feasible study on design of variable displacement pump has been evolved and submitted for further optimization

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