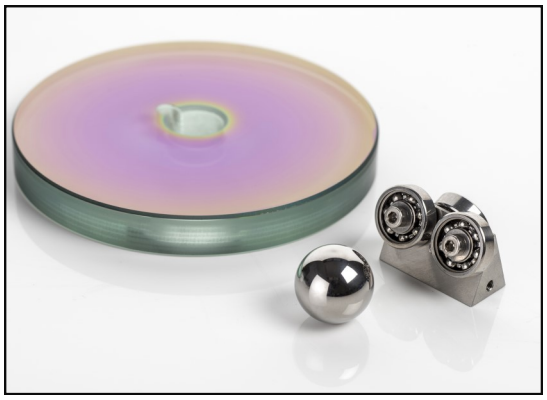
PCS Instruments

EHD2

Ultra Thin Film Measurement System



A fully automated bench top, computer controlled instrument for film thickness measurements of lubricants in the elastohydrodynamic (EHD) lubricating regime

Leaders in Tribology Test Equipment

www.pcs-instruments.com

EHD2 Rig Overview

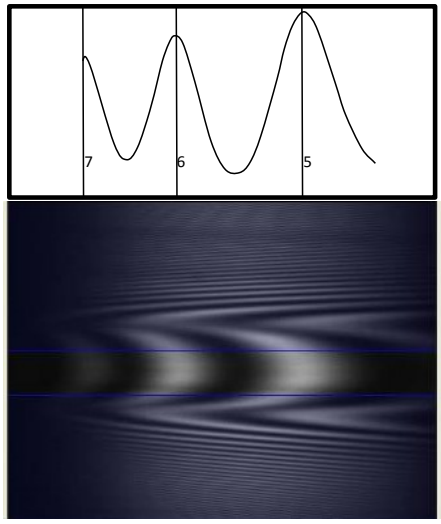
The EHD2 Ultra Thin Film Measurement System is the latest evolution of the successful EHD instrument which to date has sold over 50 systems worldwide. It is now a ***fully automated*** computer controlled instrument for measuring the film thickness and traction coefficient (friction coefficient) of lubricants in the elastohydrodynamic (EHD) lubricating regime. The instrument can measure lubricant film thickness down to 1 nm with a precision of +/- 1 nm. The contact pressures and shear rates in this contact are similar to those found in, for example, gears, rolling element bearings and cams. In addition to film thickness measurements, traction coefficients can be measured at any slide/roll ratio from pure rolling up to 100%. The instrument was developed from research work performed at Imperial College and there are currently over 90 systems in use worldwide.

Principle

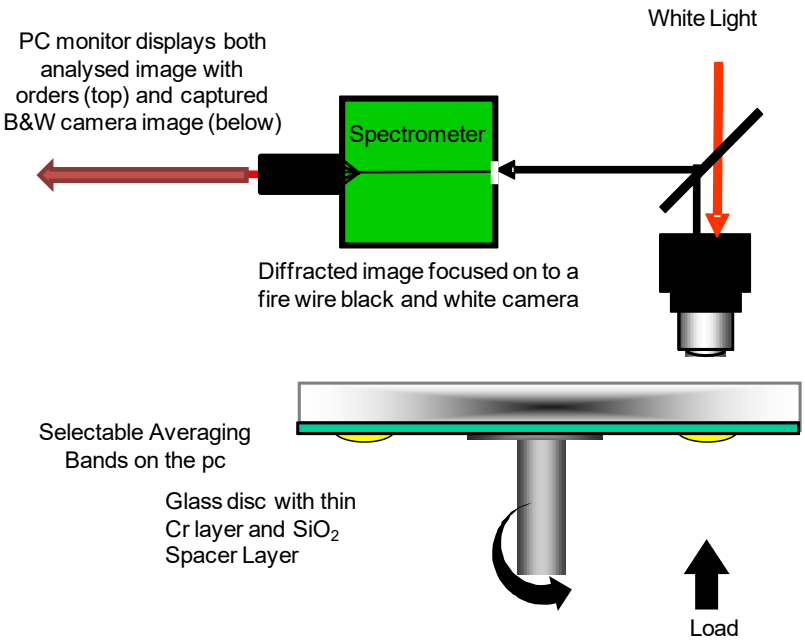
The instrument measures the lubricant film thickness properties in the contact formed between a ¾“ (19.05mm) diameter steel ball and a rotating glass disk by optical interferometry. The lubricant film thickness at any point in the image can be accurately calculated by measuring the wavelength of light at that point. Normally the system measures the wavelength of the light returned from the central plateau of the contact and hence calculates the central film thickness.

Automated testing

The control software runs on a standard PC and allows the user to easily define a test profile containing a sequence of temperatures, loads and speeds. After setting the initial film thickness, the selected profile steps the instrument through the test sequence, recording data as required, without any intervention by the user.



Interference image from ball and chrome layer



EHD2 Method

1) The contact is illuminated by a white light source directed down a microscope through a glass disc on to the contact.

2) Part of the light is reflected from the Cr layer and part travels through the SiO_2 layer and fluid film and is reflected back from the steel ball.

3) Recombining the two light paths forms an interference image which is passed into a spectrometer and high resolution black and white CCD camera.

4) The camera image is captured by a video frame grabber and analysed by the control software to determine the film thickness.

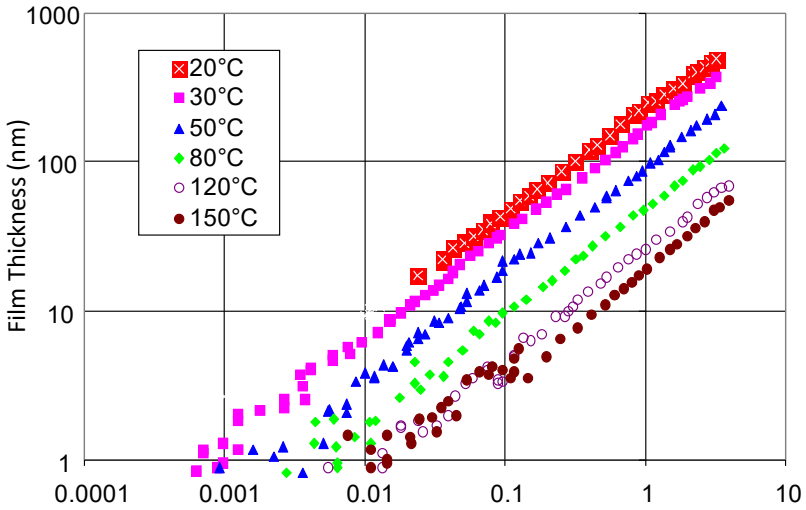
Specimens

The 3/4“ diameter plain standard ball is made from carbon chrome steel and has a high grade surface finish to ensure good reflectivity. The standard glass disc is coated with approximately 20nm of chromium and 500 nm of silica. The ball can also be drilled to allow it to be driven during the test at a set slide/roll ratio (SRR). Although the ball has to be reflective, it can be made from different materials. In the past we have supplied tungsten carbide balls (either plain or drilled) and sapphire discs to enable contact pressures up to 3 GPa.

Film Thickness Data

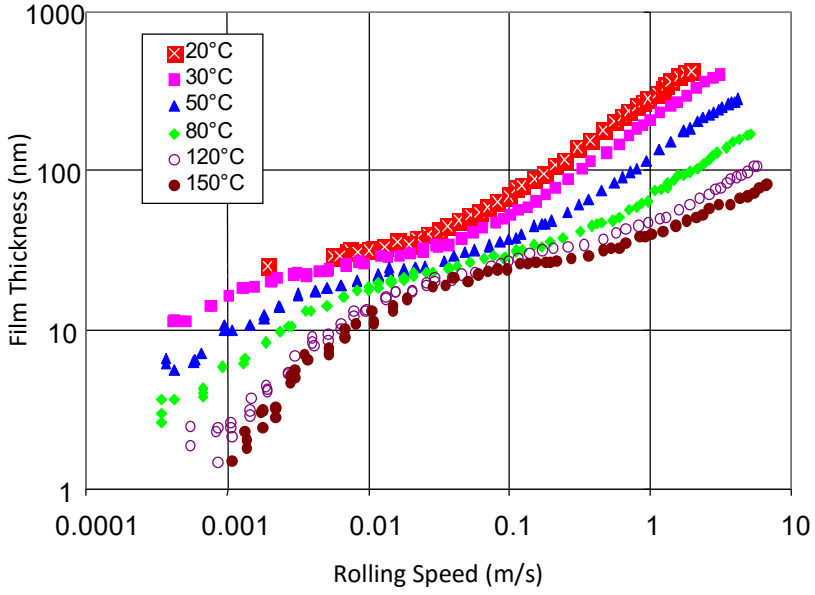
The two graphs show central film thickness (Y-axis) versus rolling speed (X-axis) at a range of lubricant temperatures.

The upper graph is for an additive-free,100 solvent neutral base oil.



The lower graph shows the same base oil with the addition of 10% wt of a viscosity index improver (dispersant poly(ethylene propylene) copolymer).

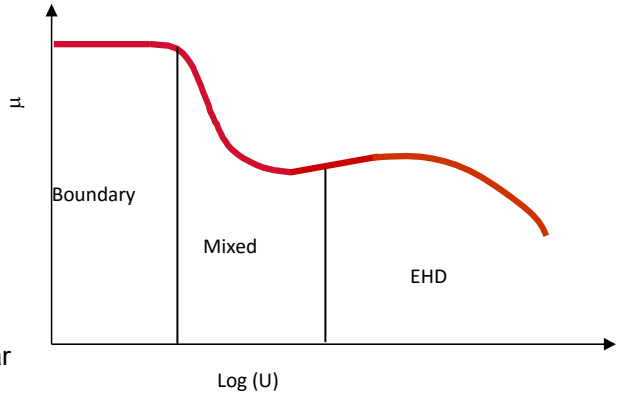
There is a marked increase in the film thickness at low speeds with the VI improver present.



Applications

Applications of the instrument include:-

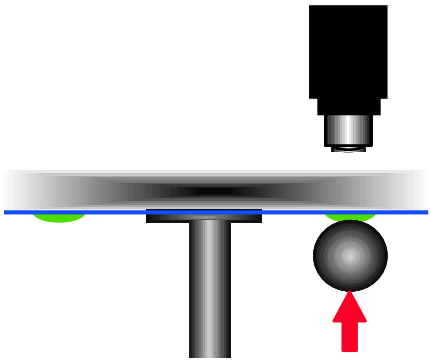
- Evaluation of film forming and frictional properties of oils and greases
- Starvation and reflow characteristics of grease lubricated components
- Fuel economy prediction of candidate crankcase oils
- Performance prediction of oil-in-water emulsion rolling mill lubricants
- Fundamental investigations of the high pressure/high shear behaviour of fluids such as liquid crystals



Spacer Layer Imaging Method (SLIM) on the EHD Rig

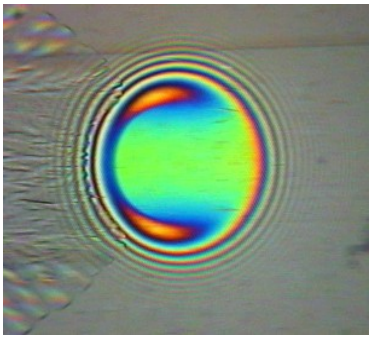
The Spacer Layer Imaging Method (SLIM) is a natural development of the EHL Thin Film Measurement System. Instead of using a spectrometer to determine the wavelength of the light returned from the image of the EHL contact, SLIM uses a high resolution, RGB CCD colour camera to grab an image of the whole contact. The SLIM software uses a previously determined colourspace calibration to match the colours in the image to oil film thicknesses.

The system can thus produce a film thickness map of the whole EHL contact in a few seconds. This makes it a unique tool for examining conditions such as parched or starved lubrication, grease lubrication, rough surface EHL and additive boundary film formation.



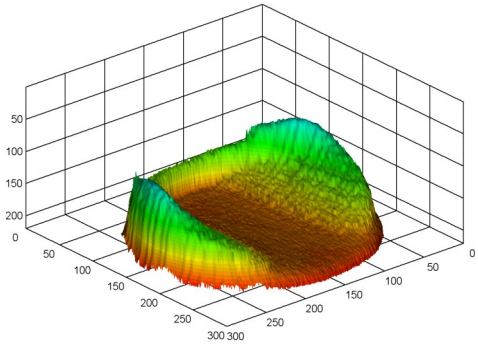
STAGE 1

Produce high resolution image



STAGE 2

Acquire high resolution digital image of contact.



STAGE 3

Use colour information to determine film thickness within contact or full contact map.

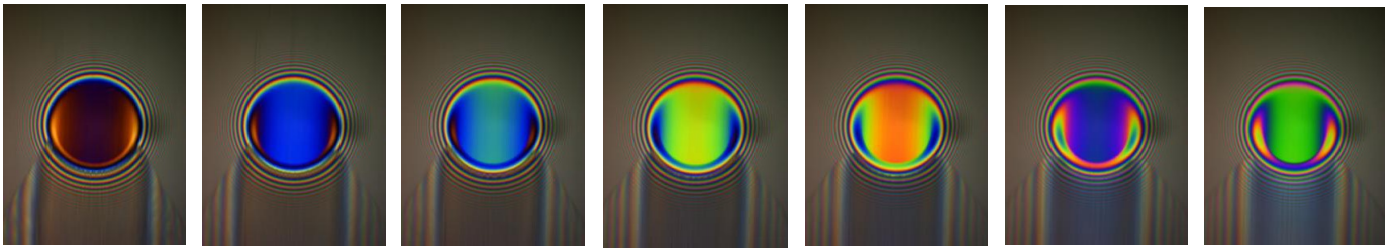
SLIM Method

Software

The software for the system comprises two parts. The first part is the control software which allows the user to conduct a test on the EHD system and acquire images of the contact under user-defined test conditions. The entire test is stored on the PC as a 'Project' and is portable as a subdirectory. Some sample screen shots of the dynamic image acquired during a test are shown below.

The second part of the software performs the off-line analysis of the images. The user loads the project into the analysis package which can produce 3D maps of any areas of interest - or the whole contact - at various spacial resolutions. Post processing of the resultant data (a matrix of film thicknesses) can be performed with the supplied software or any other suitable 3D graphing package.

Increasing speed

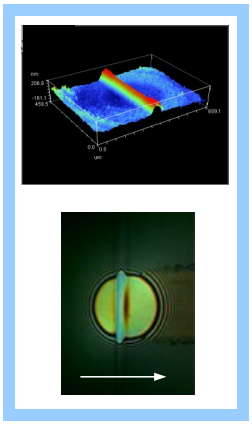


Screenshot images acquired during a SLIM test

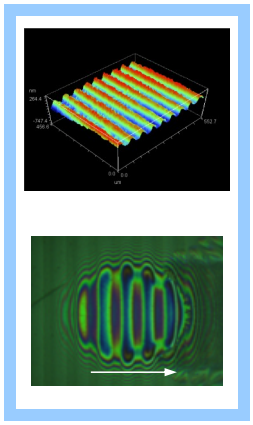
Applications of SLIM

The Effects of 3D Model Surface Roughness Features on Lubricant Film Thickness in EHL Contacts

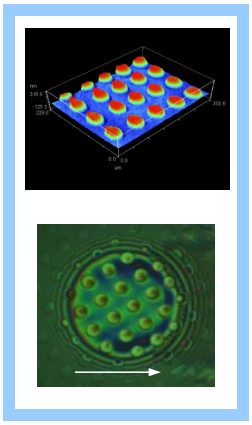
Below are some results from work performed at Imperial College[1] on the effect of different surface roughness on lubricant film thickness. A variety of surface finishes have been investigated using the 3D Mapper to measure the film thickness.



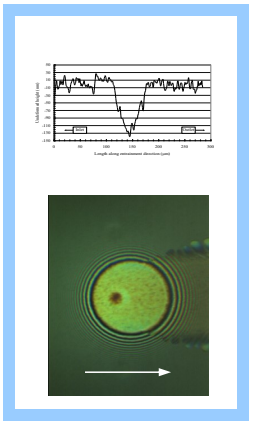
Single ridge



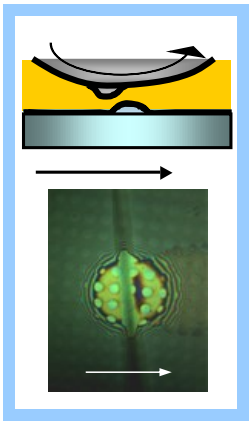
transverse roughness



isotropic roughness



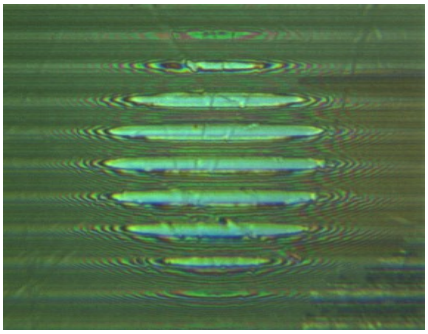
surface dent



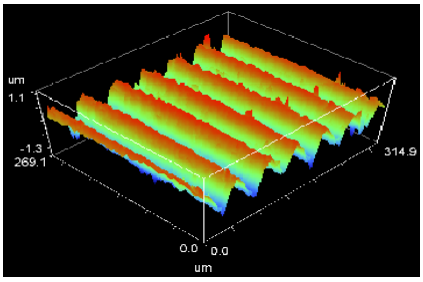
asperity collision

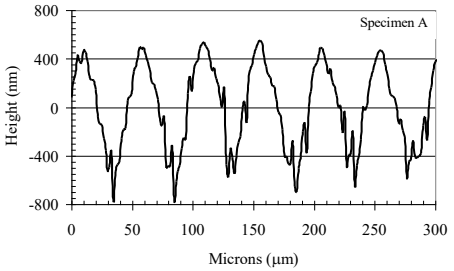
Longitudinal vs Transverse

Work performed comparing longitudinal and transverse roughness showed that the longitudinal roughness lead to a reduced dynamic lift compared to the transverse roughness and a higher proportion of the contact is borne by longitudinal asperities compared to transverse asperities.



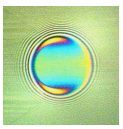
longitudinal roughness



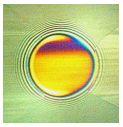


1 - From work presented by Choo, Olver, Spikes, Dumont and Ioannides at STLE conference in Las Vegas, May 2005

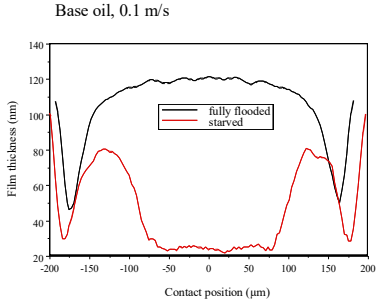
Application of SLIM to produce 2D profile through centre of contact under different lubrication conditions.



fully flooded



starved



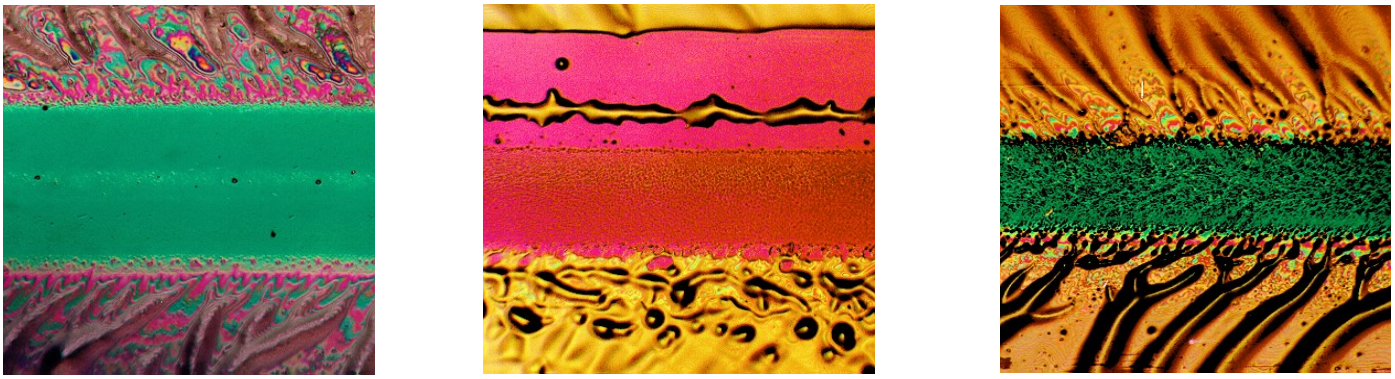
Starvation

The 3D SLIM method can be used to investigate parched or starved contacts. The images to the left show the full contact and the 2D profiles through the centre of the contact for both fully flooded and starved conditions.

Further Applications

Grease Films

The images below show residual grease films deposited on the glass spacer layer disc of the EHL system. These images can be analysed to give information about the leakage process by which the rolling track is replenished with oil from the grease matrix. This work is part of an on-going programme of research using the EHL system in the Tribology Laboratory at Imperial College, London.



Residual Grease Films on Standard Spacer Layer Disc

High Pressure Pot

With the optional high pressure pot, pressures from atmospheric to 25 Bar can be set to test both liquids and gasses. There is a pressure indicator, purge valve and sight window to observe the liquid level.

This has previously been applied to look at the effect of pressure on refrigerant gases and liquids.

EHD High Pressure Pot

Recent Publications

Some recent publications for the EHD rig are listed below. For more publications, please visit our web site www.pcs-instruments.com

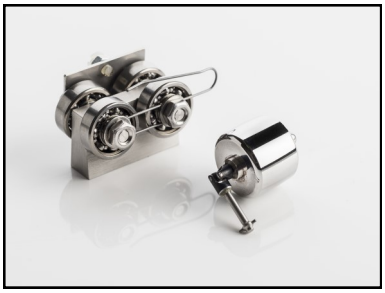
Choo, J.W., Olver, A.V. and Spikes, H.A., "The influence of transverse roughness in thin film, mixed elasto-hydrodynamic lubrication." Trib. Intern. 40, pp. 220-232, (2007).

Spikes, H.A., "Sixty years of EHL". Lubr. Sci. 18, pp. 265-291, (2006).

Cambiella A., Benito J. M., Pazos C., Coca J., Ratoi M and Spikes H.A. "The effect of emulsifier concentration on the lubricating properties of oil-in-water emulsions." Tribology Letters 22, pp. 53-65, (2006).

EHD Accessories and Contact Conditions

PCS has developed a range of accessories for the EHD rig. Some of these were developed to extend the capabilities of the instrument, such as the grease scoop which maintains grease within the contact during a test. Others were designed to meet the specialised needs of some customers, such as adapting the ball carriage to enable either an 8 mm or 1/2“ diameter ball to used instead of the standard 3/4” ball (to increase the contact pressure). Other accessories can be found on our website : www.pcs-instruments.com



Spherical Roller Carriage

The spherical roller produces an elliptical contact and can be used to generate a lower contact pressure for the same applied load. To ensure that pure rolling is maintained, the ball motor is used to drive the roller.

Cooler

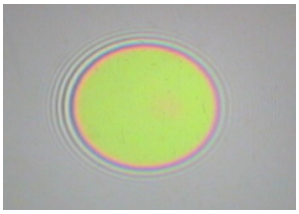
An optional cooler can be connected which circulates silicone cooling oil through the cooling ports in the pot. This can allow a quicker turn-around of tests. The EHD2 cooler comes with an associated switch-box, that automatically switches on at the end of a test and cools the pot down to a pre-defined temperature.

Grease Scoop

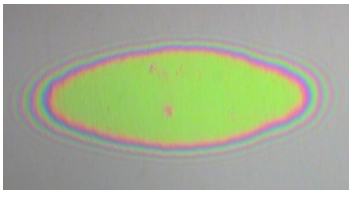
The optional greases scoop consists of a PTFE part connected to a steel block that is attached to the ball carriage. The PTFE block has a channel which guides the grease into the contact ensuring a constant supply of grease through the test.

Different Contact Conditions

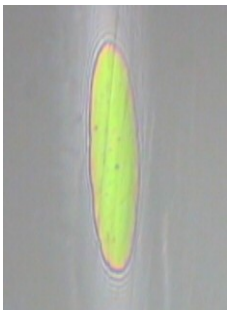
Below are images of some of the contact conditions that are available on the EHD rig.



Point Contact - Ball-On-Disc



Elliptical Contact - Spherical roller-



Edge Contact - Barrel-on-disc

Technical Specification

PCS Instruments

Specification

Film Thickness	1 to 1000 nm
Load	0 to 50 N
Contact Pressure	0 to 0.7 GPa (steel ball on glass disc)
	0 to 3 GPa (WC on sapphire)
Speeds	0 to 4 m/s
Temperature Range	Ambient to 150°C
Test Sample Volume	120 ml

Control system

PC	Custom software running on Windows XP
Safety Checks	Dual platinum RTD's for temperature measurement, Emergency stop on front cover
Power Supply	100-240V, 50/60 Hz, 750 VA

Dimensions and weight

Mechanical unit	50 x 50 x 30 cm, 25 kg
Electronics unit	50 x 44 x 23 cm, 19 kg

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