EFFECTS OF PRESSURE WAVES APPLYING ON FILTRATION

A. T. Akhmetov, A. A. Gubaidullin, and A. V. Shnaider

Tyumen Branch of Institute of Theoretical and Applied Mechanics SB RAS,
625000 Tyumen, Russia

Introduction

During experimental investigations on the vertical shock tubes of shock-wave loadings influence on the filtration a number of effects were detected. Quantitative and qualitative interpretation of these effects is given within the framework of the mechanics of multiphase systems. Filtration of distilled water under action of a hydrostatic pressure of a column of this liquid above the core is considered. The core was preliminary saturated with air. In experiments a considerable (on the order) reduction of fluid flow rate through the core with the increase of time was observed. We have named this peculiarity 'filtration blockage'. It is shown that at shock-wave loadings in the state of filtration various results are possible. During the action of the shock-wave loadings in a 'filtration blockage' peak increase of fluid flow rate is observed. Repeated shock-wave loadings resulted in increasing of the average fluid flow rate level. During the action of waves at the initial stage of filtration (before 'blockage') the opposite result was observed: reduction (by 3-4 times) of liquid flow rate. Some results of experiments on the action of compression waves on a stationary filtration are published in [1-3].

Experimental setup

The experiments were carried out on a shock tube equipped for investigation of filtration (Fig.1). The setup consists of two sections: measuring (with pressure gauges) 0.5 m long and dynamic (with system for excitation of waves) 1 m long, inner diameter of tube is 100 mm, thickness of wall is 9 mm. On the bottom flange of the shock tube there was fixed a cylindrical core, pressed in the metallic girdle (Fig. 1). The filtration was created by hydrostatic pressure of a liquid (distilled water) 1 m high column.

Preliminary dried up cores were used which were filled in by distilled water at the closed crane 5 (Fig. 1). After the crane opening the water filtered through the core preliminary saturated with air, therefore there was a residual gas phase when filtrating. At long experiments liquid volumes, filtered through the core, were compensated. For liquid flow rate measuring an electronic balance with accuracy of 5 mg was used.

The loadings were organized by shocks on the rod rigidly connected to the piston. Pressure in loading wave was registered by piezoelectric gauges shown in Fig. 1: 4 – starting, 5, 6 – registering. The signal from the gauges was amplified and processed on the computer. The amplitude of signal reached several MPa.

'Filtrational blockage' of core

After filling a tube in by distilled water up to the height of 1 m above the core crane 5 was opened (Fig. 1). At water filtration throw the core saturated with air the gas replacement process began. The weight of flowing liquid was measured. The initial flow rate in a series of these experiments was in range 100-400 mkl/min. Further on (within several days) the flow rate monotonously decreased to its minimal value (20 – 100 mkl/min).

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Abstract

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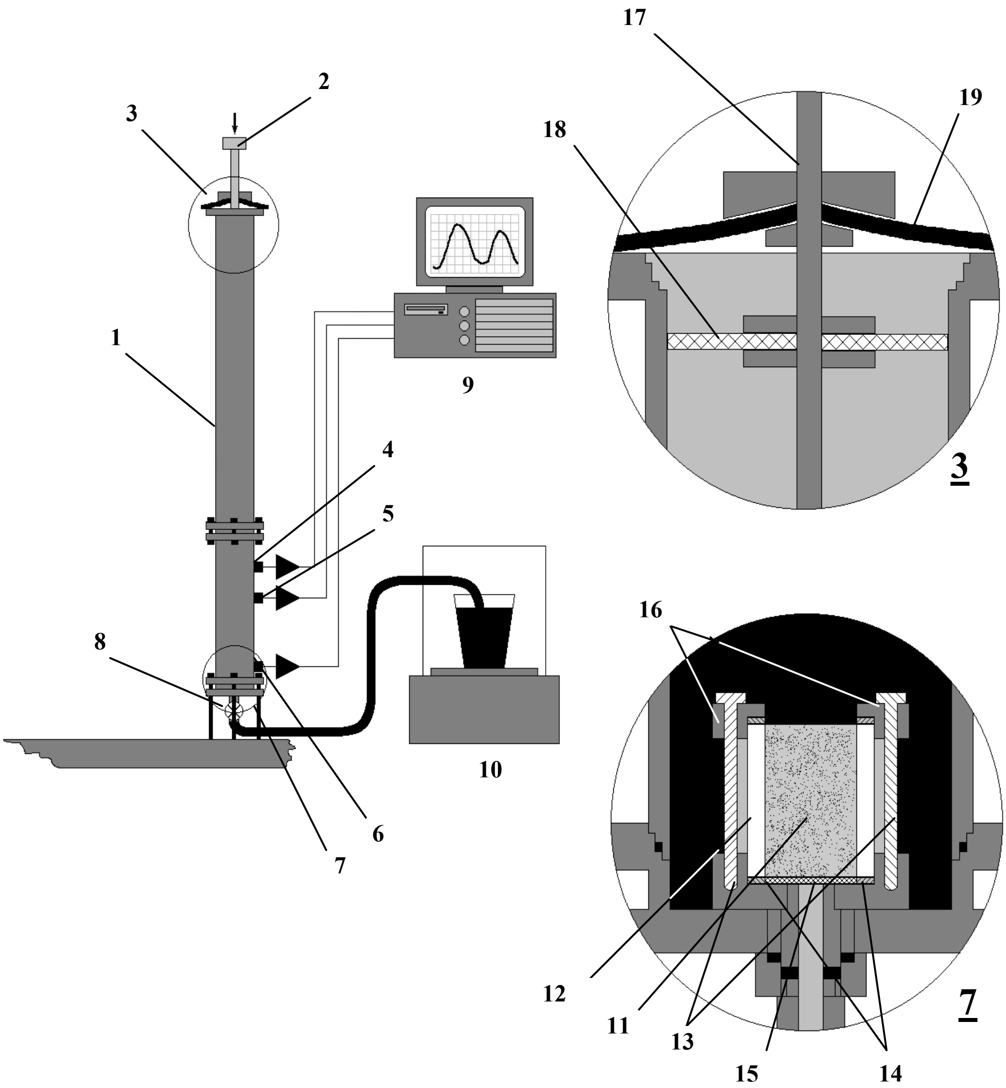

Fig. 1. Setup for investigation of influence of applying shock–wave loadings on filtrational process: 1 – shock tube, 2 – piston, 3 – shock unit, 4, 5, 6, – pressure gauges, 7 – filtrational unit, 8 – crane on the bottom flange of a tube, 9 – computer, 10 – electronic balance, 11 – core, 12 – metal holder of the core, 13 – fixing bolts, 14 – condensing fluoroplastic rings, 15 – metal lattice, 16 – holder fixing the core, 17 – piston rod, 18 – fluoroplastic disk, 19 – elastic rubber disk.

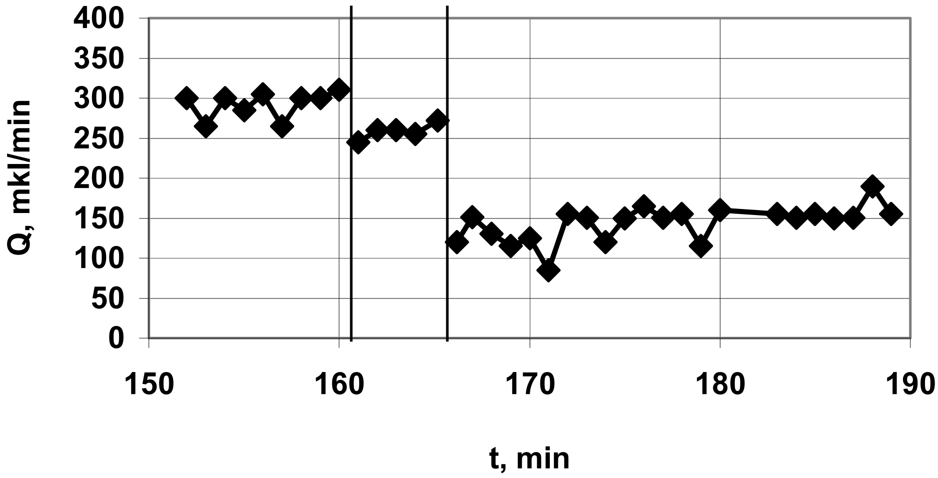

Fig. 2. Effect of 'shock blockage' at applying pressure waves on the liquid filtration through a core with residual gas phase. Dashed lines correspond to shocks.

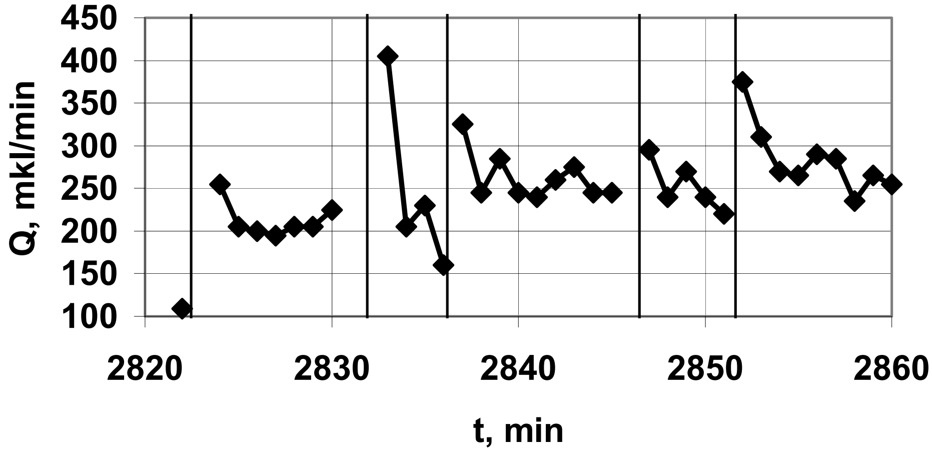

Fig. 3. Effect of peak increasing of flow rate at applying pressure waves on the liquid filtration through a core with residual gas phase. Dashed lines correspond to shocks.

The described phenomenon obtained the name of the core 'filtrational blockage' effect. It is possible to offer the following explanation of 'filtrational blockage': in flow process from the top to the bottom of the core the dissolved in liquid gas under pressure difference begins to exude from the bearing liquid. The formed gas bubbles grow and, in part detained in pores, gradually block them. As a result residual gas saturation is considerably increased which causes appreciable reduction of permeability and the flow rate.

'Shock blockage' of a core

Influence of compression waves at an early stage of filtration before filtrational blockage results in sharp decrease of the filtered water flow rate (Fig. 2). Loadings at the flow rate of 300 mkl/min have resulted in instant decrease of the flow rate to 100 mkl/min, i.e. core blockage happened as a result of shock-wave loadings - 'shock blockage'. The further core loadings do not result (Fig. 2) in change of the liquid flow rate. For an explanation of this effect it is possible to suppose that at wave applying there is a liberation of gas from a filtered liquid, and the formed bubbles block the core.

Peak increase of the filtered liquid

It was determined, that after the first shocks the flow rate increases by 2 - 3 times in comparison with the value formed in filtrational blockage process (Fig. 3). During the following 10-20 min slow reduction of the flow rate with stabilization at a new level is observed. It is interesting that after stabilization the flow rate appears higher than before the shock. Difference of levels from shock to shock decreases. The flow rate grows to some maximal value for the given core after which the influence of shocks becomes negligibly small.

It is possible to offer the following explanation of the obtained effect. The wave taking place on the core beats out bubbles from a steady motionless position that results in peak increase of permeability, and hence, the flow rate. However such phenomenon has short-term character due to its instability, which explains following reduction of the flow rate. Nevertheless, repeated loadings result in some integrated changes which result in increase of the average level of liquid flow rate.

Conclusions

As result of investigation the following basic conclusions may be made:

1. At filtration of water through a core saturated with gas at the time the flow rate multiply decreases, i.e. filtrational blockage of core effect displayed.

2. At repeated loadings in early stage of filtration before filtrational blockage display the shock blockage is observed.

3. At shock loadings of blocked cores in late stage of filtration peak growth of the liquid flow rate is observed. At repeat loadings average level of the flow rate grows up to some limiting value.

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