

# 偏心分注水力声波解堵增注技术

吴荷香 宋秉忠 李家明

王凯

(河南油田分公司石油工程技术研究院, 河南南阳 473132) (河南油田分公司采油一厂, 河南桐柏 474780)

**摘要** 针对老油田开发现状及存在的问题, 开展了偏心分注水力声波解堵增注技术研究。介绍了该技术的组成、工艺原理、主要技术参数、技术特点及现场应用情况; 叙述了主要配套工具 PXS B-115-25/120 偏心水力声波发生器的结构及工作原理。现场应用结果证明: 该技术施工工艺简单、投资少、有效期长, 是用于注水井解堵增注较经济有效的方法。

**关键词** 注水井 分层注水 声波 解堵 增注 研究 应用

**作者简介** 吴荷香, 1989年毕业于重庆石油学校采油工程专业, 现在采油所从事采油技术研究。宋秉忠, 现在采油所从事采油工艺技术研究。李家明, 1987年毕业于西南石油学院计算机专业, 现在采油所工作, 高级工程师。王凯, 1994年毕业于石油大学石油地质专业, 工程师。

河南稀油油田已进入特高含水开发后期, 注采结构研究表明, 仍有 31.1% 的油井和 31.2% 的油层产液差、动用程度低, 与其相对应的 28.1% 的注水井和 31.2% 的注水层吸水差, 达不到配注要求, 严重影响着油田的稳产。引起注水井欠注的主要原因有 2 个: (1) 钻井或井下作业对地层的污染, 造成储层伤害; (2) 注入水中机械杂质含量超标, 垢离子等杂质对地层近井地带造成堵塞。为了解除欠注井近井地带堵塞, 开展了偏心分注水力声波解堵增注技术的研究。现场应用表明: 欠注层基本达到配注要求, 改善了老油田的开发现状, 减缓了油田的递减速度, 提高了水驱动用程度和最终采收率, 提高了油田整体开发水平。

## 一、声波作用机理

1. 声波作用于地层 由于传播媒质(岩石、粘附物、水)的密度不同, 其声阻也不相同, 所以声波在各媒质中的传播速度也不尽相同, 且差异很大。声波在传播时各媒质质点相对振动, 从而在岩石与粘附物的界面处产生剪切应力, 使 2 种相态物质界面产生相对位移(位移效应), 削弱了岩石和粘附物的亲和力, 使粘附物从岩石脱落, 并在声波的机械振动下将其破碎, 解除地层堵塞, 提高地层渗透率。

2. 声波作用于油层 油层内毛细管在声波的机械振动作用下直径会发生时大时小的变化, 打破了原有注入的平衡状态。当毛细管胀大时, 其表面张力减小, 增大了油层的有效孔隙体积。

3. 声波作用于注水系统 一方面由于声波的机械振动破坏了原来的细菌生长及垢离子的结晶条件, 从而抑制了地层和注水管柱中细菌的生长、聚集及垢离子结晶, 防止地层二次堵塞; 另一方面声波振动能使注入污水中机械杂质颗粒破碎, 改善了注入水质, 减缓了对地层的伤害。

## 二、偏心水力声波发生器及其性能测试

1. 组成 偏心水力声波发生器主要由工作筒和水力声波振荡器 2 大部分组成。结构如图 1 所示。

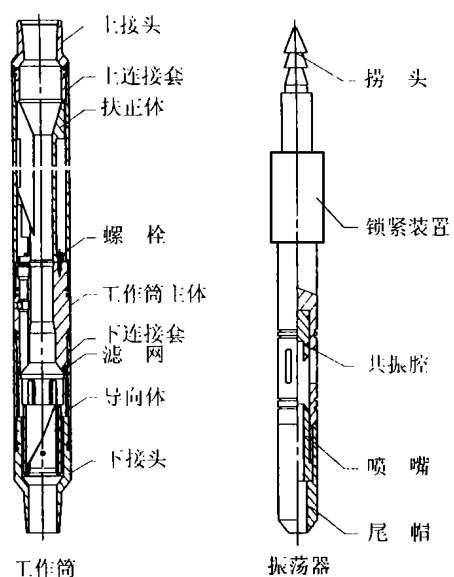


图 1 偏心水力声波发生器结构示意图

2. 工作原理 注入水通过水力声波振荡器的喷嘴高速喷出,形成高压水柱射入共振腔,共振腔内压力急速上升到一定压力时形成反射水柱,该反射水柱与喷嘴喷出的高压水柱汇合向外喷射,使共振腔内压力迅速降低,这时又有喷嘴喷出的高压水柱给予压力补充,在此循环过程中,喷嘴喷出的高压水柱和共振腔反射水柱的衔接处形成向四周喷射的水力脉冲波,产生声波。

3. 设计参数优选试验 为了研制功率大、效率高的声波发生器,必须对各参数之间的关系进行试验研究,取得最佳参数组合,为此设计了7种不同直径喷嘴的水力声波发生器,其喷距、共振腔深度均可调节;进行了参数优选系列试验,试验流程如图2所示。由泵循环出来的流体激励水力声波发生器产生声波,由水听器 and 示波器测量声波的振幅和频率,由阀门控制流量或流速,分别调节喷距和共振腔深度,获得在每种喷嘴直径条件下喷距、共振腔深度的最佳参数组合,使声幅值最大。

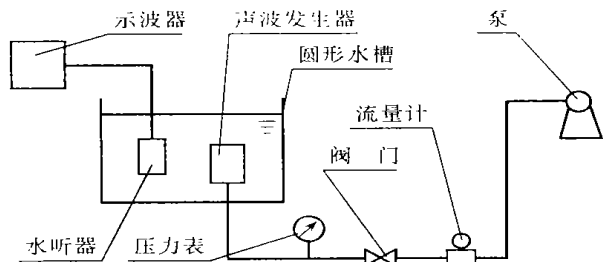


图2 参数优选试验流程示意图

试验表明,在各种喷嘴直径条件下流量在 $14.6 \sim 102.1 \text{ m}^3/\text{d}$ 时所选配合参数(喷距、共振腔深度)声幅值最小为 $19.4 \text{ V}$ ,最大为 $27.9 \text{ V}$ 。根据试验所得参数,设计研制了偏心水力声波发生器。

4. 声波参数测试试验 偏心水力声波发生器是靠流体来激励产生声波的,声波幅值大小与流量有紧密关系,为了确定使声波幅值尽可能地大的流量范围,进行了各种型号喷嘴的偏心水力声波发生器在不同流量和距离下的声波幅值测试。试验流程如图3。偏心水力声波发生器置于射孔套管内,由泵循环出来的流体激励偏心水力声波发生器产生声波,由水听器和示波器测试声波频率和幅值。上提或下水听器或变换测试口,可测径向、轴向不同距离之处的声波频率和幅值,调节流量测声波幅值与流量的变化关系。

试验得知,随测点距离的增加,声波幅值减小;流量增大,声波幅值增加,但流量增大到一定值时声

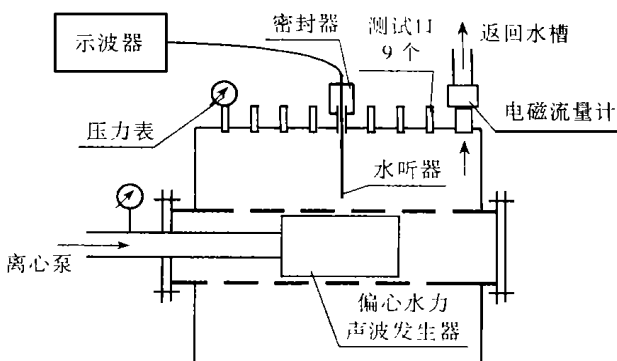


图3 室内试验装置工艺流程

幅值增加幅度趋于平缓,由此而确定各喷嘴的这一流量为偏心水力声波发生器的最佳流量,从而得出偏心水力声波发生器适应的流量范围。对不同喷嘴的偏心水力声波发生器,流量最小为 $20 \text{ m}^3/\text{d}$ ,最大为 $172 \text{ m}^3/\text{d}$ 。声波幅值最小为 $9.1 \text{ V}$ ,最大为 $12.6 \text{ V}$ 。由声波幅值计算声压最小 $0.3 \text{ MPa}$ ,最大 $0.42 \text{ MPa}$ 。

5. 注入污水中的机械杂质颗粒破碎试验 采用喷嘴直径为 $4.2 \text{ mm}$ 的水力声波发生器,将注水井井口取得的污水 $0.8 \text{ m}^3$ 灌进污水池,搅拌均匀并取样(前样)测试颗粒粒度分布后,启动水泵,将污水经水力声波发生器进行处理,流量在 $2.95 \text{ m}^3/\text{h}$ 下激励 $20 \text{ min}$ ,基本为1个循环,试验结束后将处理后的污水搅拌均匀取样(后样),再测试颗粒粒度分布。

试验结果表明:注入污水经水力声波发生器处理后,粒径 $1 \sim 2 \mu\text{m}$ 的颗粒分布增加了 $6.11$ 个百分点,而大于 $2 \mu\text{m}$ 的颗粒分布都有不同程度的减少。在前样中,粒径 $4 \sim 7 \mu\text{m}$ 的颗粒分布相对较多,声波处理后,它减少得最为明显,说明水力声波振荡对机械杂质颗粒具有破碎作用。

### 三、工艺组成及技术原理

1. 工艺组成 偏心分注水力声波解堵增注管柱结构如图4所示,主要由PXSB-115-25/120偏心水力声波发生器、Y341-114-20/120封隔器、KPX-114-20/120偏心配水器、撞击筒、循环阀、筛管和丝堵等组成。

2. 工艺原理 偏心分注水力声波解堵增注技术是对具有一定吸水能力而达不到配注要求的层段进行解堵,其技术原理是:将偏心水力声波发生器与偏心分层注水管柱一起下入井下,将偏心水力声波发生器正对着需要解堵的层段,在注水过程中,对于需要增注的层段,依靠高压水流激励水力声波发生器形成振荡,产生较大能量的低频水声波作用于地层,对地层进行长期连续的解堵。

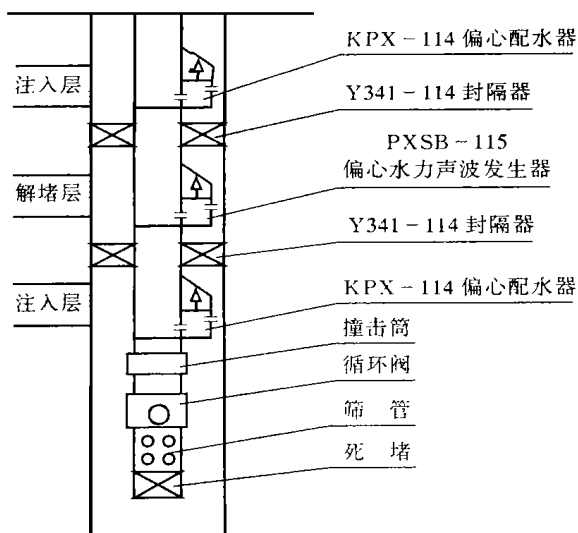


图4 偏心分注水力声波解堵增注管柱

全配套,可对偏心分层注水井的任意层段进行解堵;

(2)偏心水力声波发生器的防堵塞设计,使杂物不易聚集沉淀,保证了成功率;

(3)定压开启装置,不仅实现了免投死嘴子坐封封隔器的工艺,还保证了优化设计参数的准确性,使声强达到最大值,保证解堵效果;

(4)无需外载其它能源,仅靠高压注入水激励偏心水力声波发生器产生声波,在注水井正常注水的过程中对地层进行长期连续的解堵增注;

(5)该技术施工工艺简单,成本低。

#### 四、现场应用

截至2001年7月底,该技术已在河南油田现场应用18口井,工艺成功率100%,有效率94.4%。在可对比的12口井中,解堵层段17个,平均单井增注 $2\text{m}^3/\text{d}$ ,累计增注 $5.21 \times 10^4 \text{m}^3$ ,取得了较好的经济效益和社会效益。典型井例施工前后有关数据见下表。

3. 主要技术参数 耐压 25MPa, 耐高温  $120^\circ\text{C}$ , 声压 0.36MPa, 频率 1.5kHz。

#### 4. 工艺特点

(1)与现有的分层注水管柱和投捞测试工艺完

典型井例施工前后效果对比表

井号	施工日期 年.月	施工前			施工后			平均增注 $/\text{m}^3 \cdot \text{d}^{-1}$	累计增注 $/\text{m}^3$
		配注水量 $/\text{m}^3 \cdot \text{d}^{-1}$	水嘴 $/\text{mm}$	分层水量 $/\text{m}^3 \cdot \text{d}^{-1}$	配注水量 $/\text{m}^3 \cdot \text{d}^{-1}$	喷嘴直径 $/\text{mm}$	分层水量 $/\text{m}^3 \cdot \text{d}^{-1}$		
T7-928	1999.09	60	空	16	60	4.2	19	21	7070
		40	空	23	40	4.2	41		
H142	2000.02	40	空	23	40	4.8	47	33	8560
		50	空	40	50	4.2	55		
S211	2000.08	90	空	71	90	5.2	95	48	6730
		60	空	47	60	4.5	71		
T477	2000.11	40	空	32	40	4.0	44	31	2980
		40	空	29	40	4.0	48		

#### 五、结论

1. 该技术对有一定吸水量而达不到配注要求的注水井具有较好的解堵增注作用。

2. 水力声波振动具有对机械杂质颗粒的破碎作用,使大颗粒破碎成细小颗粒,防止和减缓了地层的再次堵塞。

3. 偏心水力声波解堵增注技术完全与偏心分层注水管柱配套,采用成熟的测试投捞工艺可顺利投捞测试。

2 Shackleton J. European Technology Update. World Oil, 1995, 216(7)

3 王鸿勋,张琪著.采油工艺原理.北京:石油工业出版社,1989

4 张仲宏等.注入水中悬浮固体微粒对地层损害的机理研究.科技论文集.油气田开发工程.北京:石油工业出版社,1996-06:465~472

(收稿日期 2001-05-08)

(修改稿收到日期 2001-08-20)

[编辑 付丽霞]

#### 参 考 文 献

1 汪伟英.注水井解堵增注技术综述.钻采工艺,1995,(4)

field. The spend acid should be disposed before it is discharged. The compound acid is developed after experiment of selecting the type and concentration of acid, selecting additives and analyzing spend acid. Field testing at offshore Oilfield SZ36-1 are successful.

**Subject heading** offshore field acidizing acidizing fluid plug removing environmental protection

### **RESEARCH OF SALT-RESISTING COLLOIDAL DISPERSION GELS**

by Wu Jiazhong, Wang Zhengliang (Jiangnan Petroleum Institute), Wang Zhiyong, Shi Bozhong

**Abstract** A new system of salt-resisting colloidal dispersion gels (CD gels) is researched and prepared. It contains nonionic polyacrylamide whose appropriate degree is from 800 mg/L to 1500 mg/L, acetic chromium whose appropriate degree is from 80 mg/L to 160 mg/L and formaldehyde whose degree is from 200 mg/L to 400 mg/L, etc. The CD gels have good salt-resisting and good water shutoff properties. Sixteen wells is efficacious within the eighteen field testing wells. Good effectiveness is achieved after field test.

**Subject heading** depth profile control colloidal dispersion gels salt tolerant property research field testing

### **TECHNOLOGY OF PREVENTION OIL STOLEN AND GAS CONTROL SYNERGY IN OIL PUMPING**

by Huang Xuebin (No. 1 Production Plant, Zhongyuan Oilfield Co.), Chen Xuezhong, Tan Qingxian, Pan Weiguo, Dong Lixia, Jia Zonghua

**Abstract** In Wenliu Oilfield, the normal production of oil well was affected by oil stolen from casing, since the ratio of gas and oil is higher, the production fluid level is higher and the energy of oil well is more abundance. According to this problem, casing oil stolen prevention sealing valve was developed, matching with down-hole oil-gas separator and gas lift valve lift technology. After the gas-fluid has been separated by the downhole separator, the gas got into annular space of casing and tube. With the oil stolen prevention sealing valve, annular space was sealed, then the gas could get into tube when its pressure is high enough to open the gas lift valve, this made the pressure of tube-casing annular space balanced. Since field test effect is obvious, a new route was afforded to likely oilfield.

**Subject heading** oil pumping prevention air lock oil stolen gas lift valve application

### **APPLICATION OF SAND CONTROL TECHNOLOGY FILLED ONLY ONE TIME WITH PACK AND HIGH PRESSURE**

by Wang Song, Chen Laiping, Chen Guang (Hekou Oil Production Plant, Shengli Oilfield Co.), Wang Heliang

**Abstract** To be filled in or out of the tube is the develop tendency of the sand control technology with gravel filled, so filled only one time with pack and high pressure dose. The principles, tool structure, and construction procedure were introduced, and the design method of the main parameters, such as discharge capacity, pressure were expounded. It was introduced that the technology has been used in old well with single or more beds, new wells, inclined wells and wells with siltstone. It has more advantages such as shorter construction period, longer sand control efficiency period, stranger applicability, and higher fluid production intensity. The higher integrate benefit of it has been obtained.

**Subject heading** pack high pressure sand control in or out of tube filling application

### **TECHNOLOGY OF PLUG REMOVAL INJECTION INCREASE WITH ECCENTRICITY SEPARATE LAYER WATER INJECTION HYDRAULIC SOUND WAVE**

by Wu Hexiang, Song Bingzhong, Li Jiaming (Petroleum Engineering Academe, Henan Oilfield Co.), Wang Kai

**Abstract** The research of technology of plug removal injection increase with eccentricity separate layer water injection hydraulic sound wave was developed according to the state and the problem of old Oilfield development. The technology principle and characteristic, the main technique parameters, and the field test were introduced. The structure and working law of the main matching tool PXS-115-25/120 was narrated. Field application showed that this technology had some advantages such as simpleness technique, little investment, longer efficiency period.

**Subject heading** water injection well separate layer water injection sound wave plug removal injection increase research application

### **DEOXIDATION OF OILFIELD INJECTION WATER AND VACUUM SEPARATOR WITH CYCLONE WATER DEOXIDATION**

by Zhang Xuewen, Zhang Yongxing (Chuankou Technique Research Institute of Petroleum), Li Danyan

**Abstract** The dissolution oxygen in injection water not only erode pipeline and water injection equipment, but also affect oilfield development effect, so a correlation criterion was made by CNPC. Every kind of deoxidize fashion in field water flooding were analyzed. The disadvantages of each fashion were pointed out. It was put forward to use vacuum separator with cyclone water deoxidation instead of existence equipment. The main work principium of this new technology was discussed in detail, and the advantages of it using in field water injection were analyzed.

**Subject heading** oil and gas fields water flooding deoxidation vacuum separator