Ansys
INNOVATION
CONFERENCE
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# 涡旋压缩机管路振动分析及优化


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Ansys

# 目录

- 背景介绍
- 问题描述
- 有限元分析
- 改善方案
- 结论

# 背景介绍

1. 丹佛斯商用压缩机产品系列

- 拥有全系列的空调，热泵，冷冻产品
- 从 2.5吨 - 350 吨的空调和热泵应用
- 从20瓦 to 20 千瓦 冷冻应用

冷冻

往复式压缩机



涡旋式压缩机



机组

空调

热泵

涡旋压缩机

变频压缩机

天磁 磁悬浮压缩机

# 背景介绍

## 2. 丹佛斯商用压缩机广泛应用于社会生活的各个领域

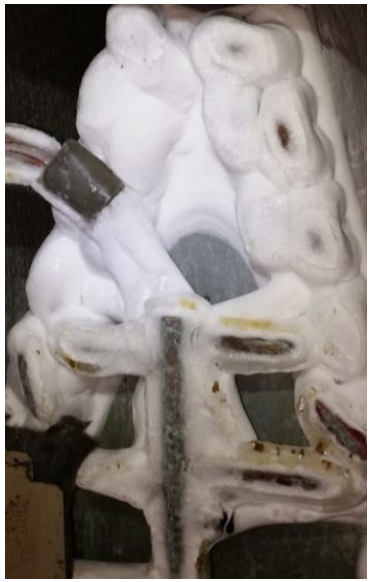
**空调**

**商业制冷**

**工业制冷**

**视频零售**

# 3. 空调系统管路泄漏问题



引起管路泄漏的5大原因

1. 系统压力过高
2. 管路腐蚀
3. **振动过大**
4. **管路强度**
5. 焊接质量

**管路泄漏的危害:**

- 系统不能进行制冷或制热
- 因缺油或过热造成压缩机损坏

**怎样验证**

- 系统管路振动测试和应力测试
- 通过有限元分析，找到设计的薄弱点

# 4.客户质量问题的解决

- 传统方案

工程师

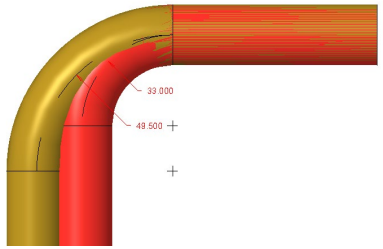
出差

客户

反馈周期长(2~3月);

资源消耗多（人力物力）

- 有限元计算方案

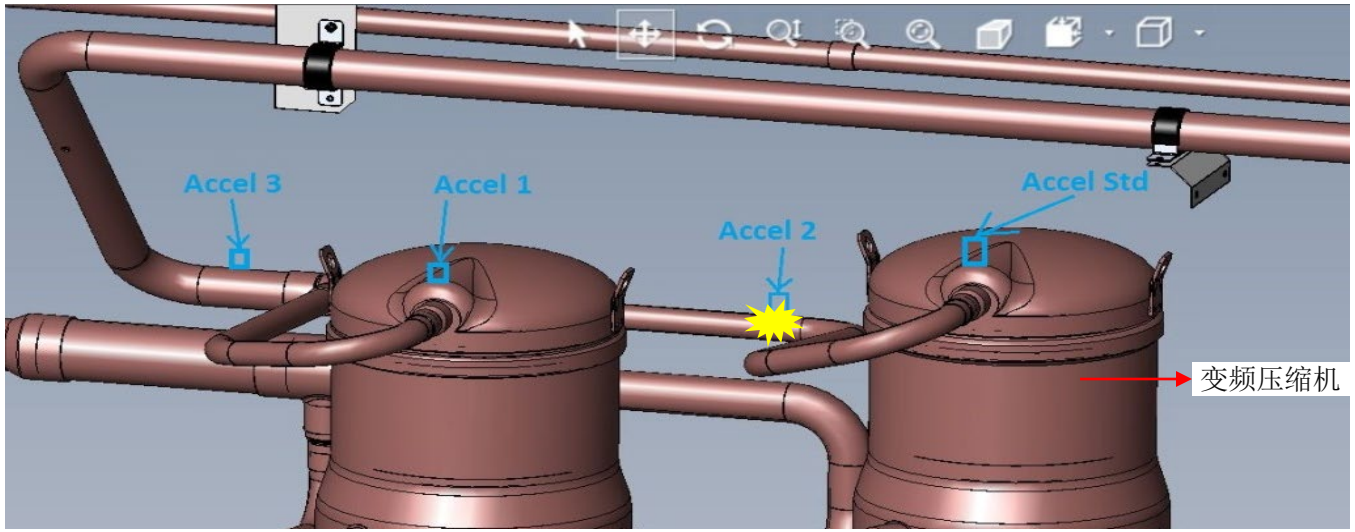



设计改善

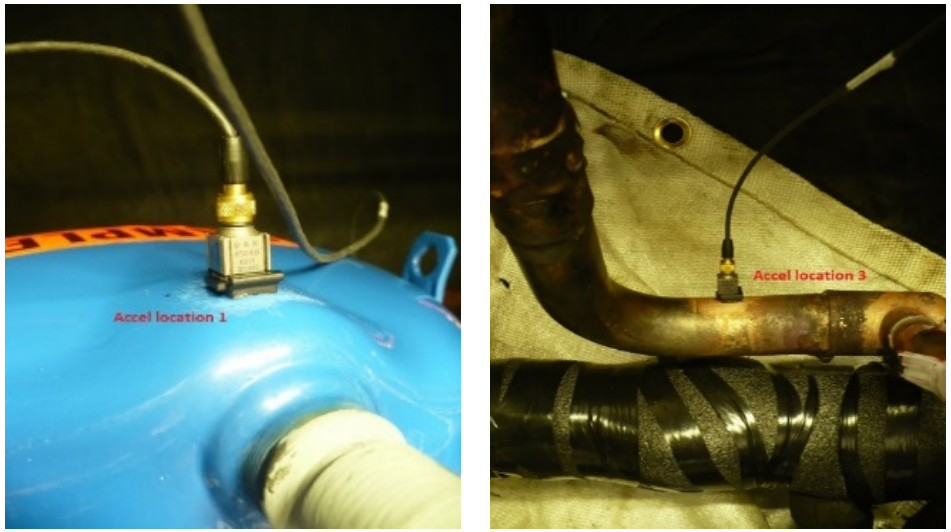
实验室测试

# 问题描述

客户D自主设计的压缩机管路，经测试发现振动过大，请求丹佛斯协助原因分析并提供改善方案

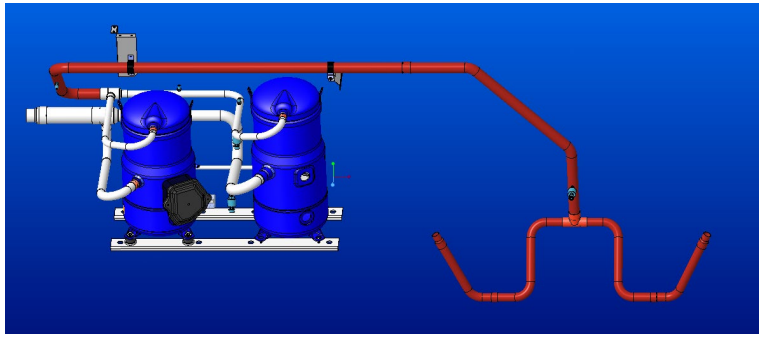



客户管路系统振动测试-传感器布点分布



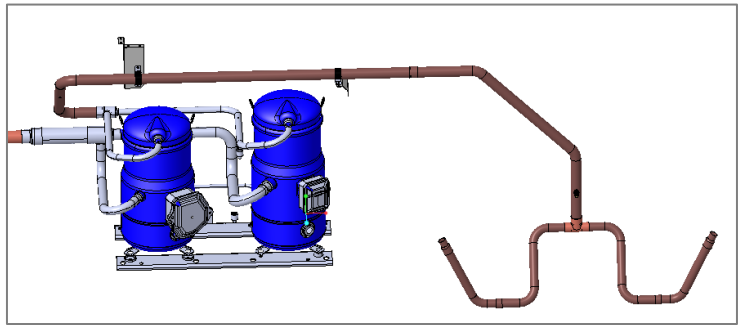

加速度传感器

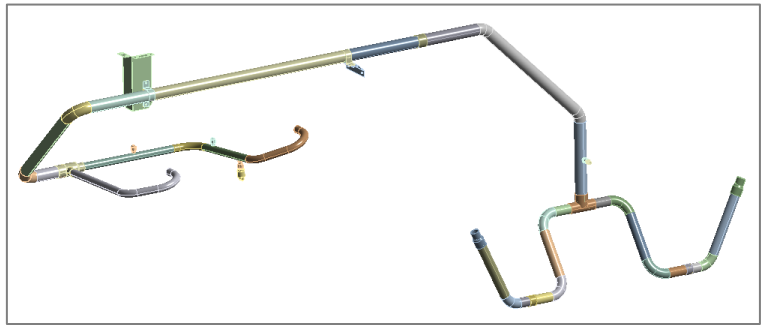
- 最大振动位移发生位置：变频压缩机排气管位置Accel2处.
- 最大振幅：390微米（标准为最大振幅不超过200微米 ）.
- 压缩机运行情况：变频压缩机运行范围从25Hz到100Hz
- 测试场所：客户D实验室



# 有限元分析

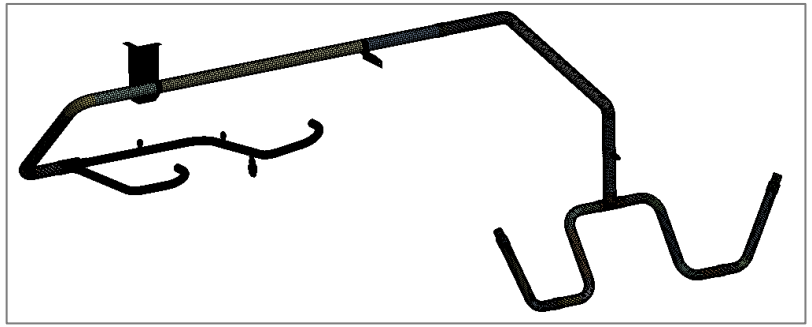
(1)模型的简化

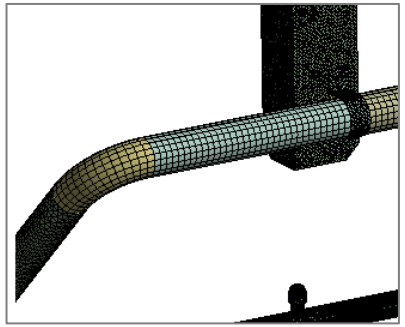




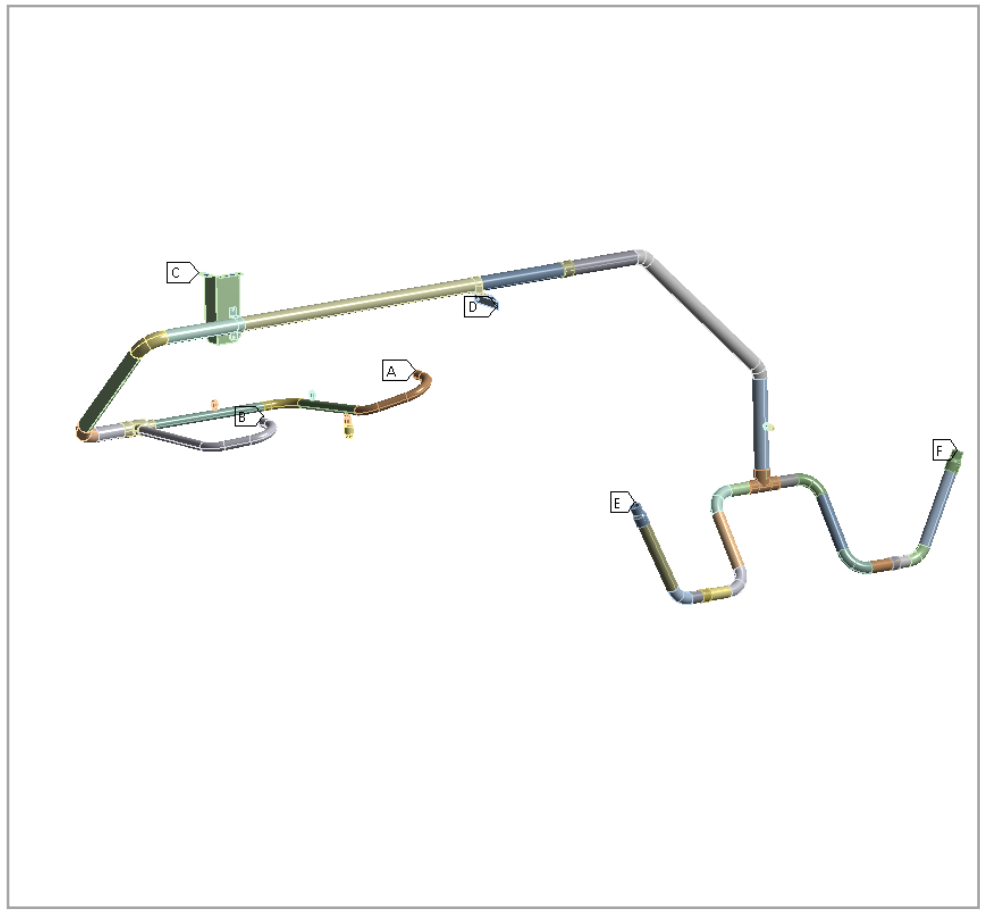
(2)材料属性的设置

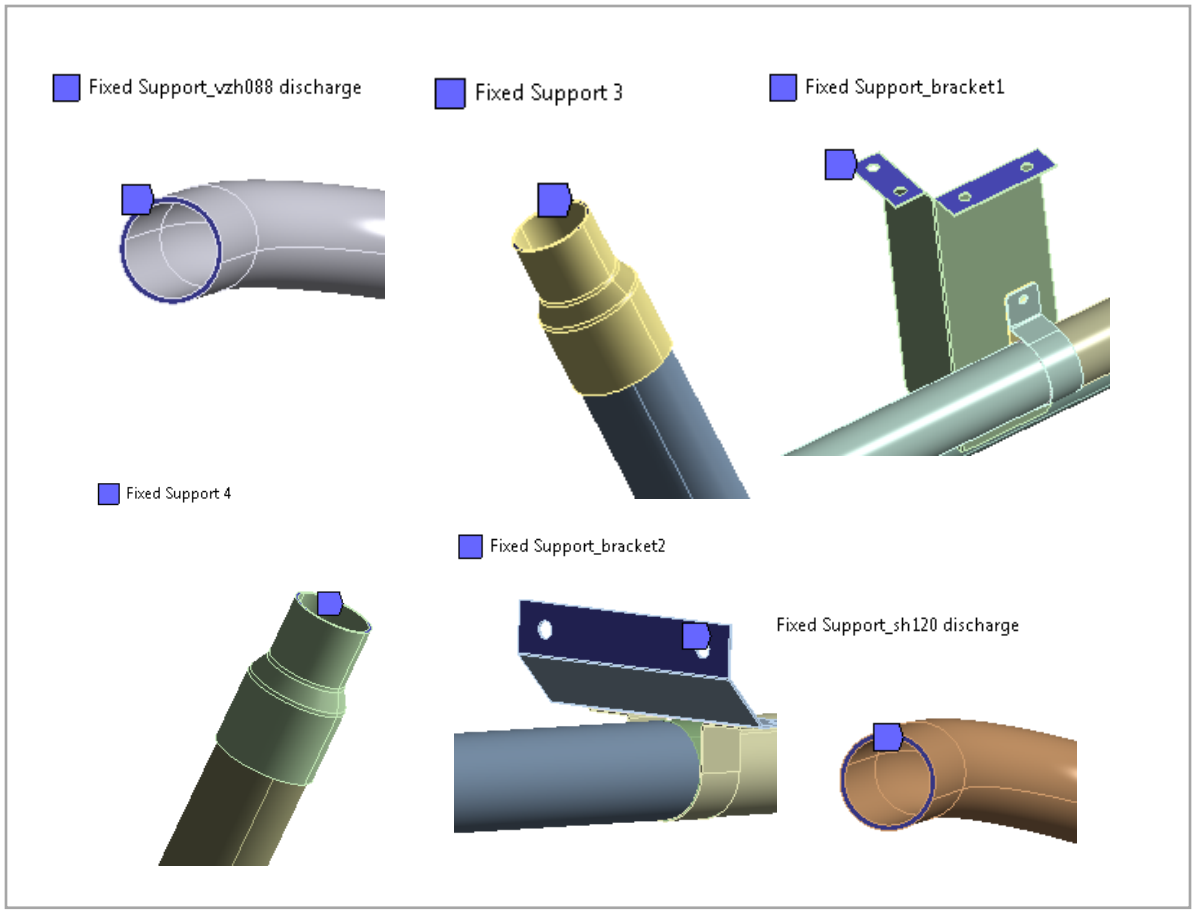
(3) 网格划分





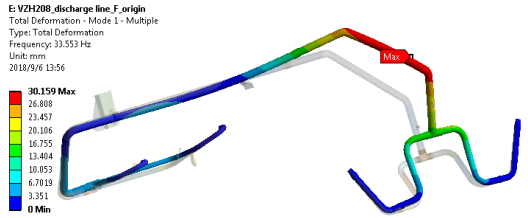
# (4)边界条件的设置



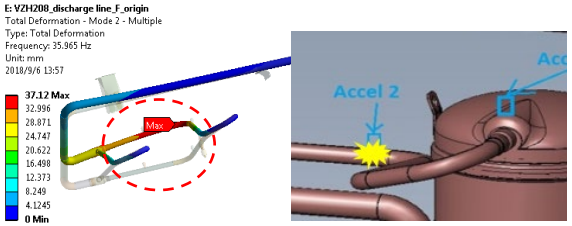



# (5)模态分析结果

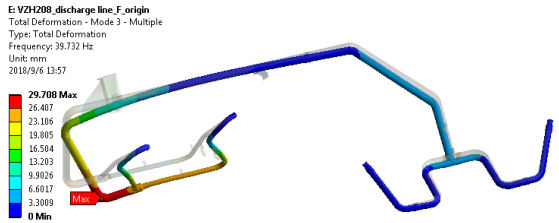
第一阶模态频率: 33.6Hz



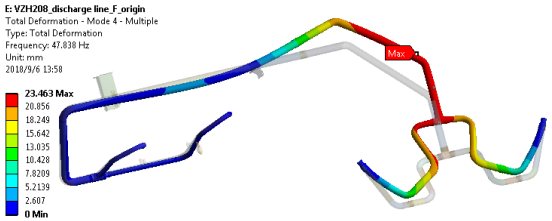

**第二阶模态频率: 36.0Hz**



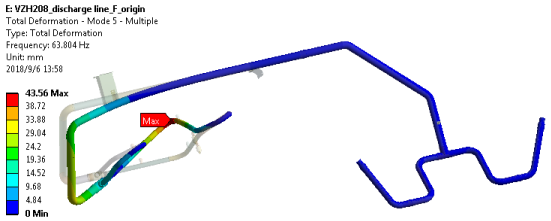

第三阶模态频率:39.7Hz



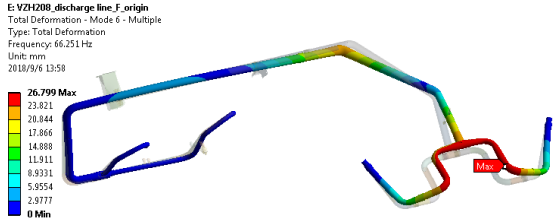

第四阶模态频率:47.8Hz



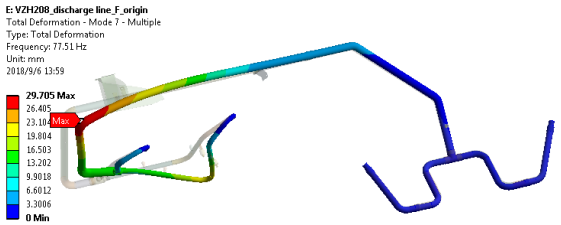

第五阶模态频率: 63.8Hz



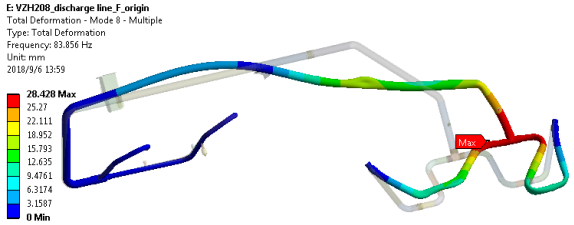

第六阶模态频率: 66.3Hz




第七阶模态频率: 77.5Hz



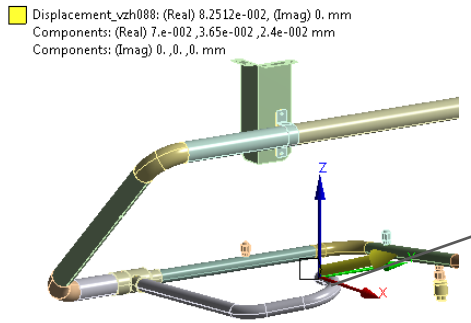

第八阶模态频率: 83.86Hz




| Mode | Frequency [Hz] |
|---|---|
| 1. | 33.553 |
| 2. | 35.965 |
| 3. | 39.732 |
| 4. | 47.838 |
| 5. | 63.804 |
| 6. | 66.251 |
| 7. | 77.51 |
| 8. | 83.856 |
| 9. | 109.18 |
| 10. | 112.86 |

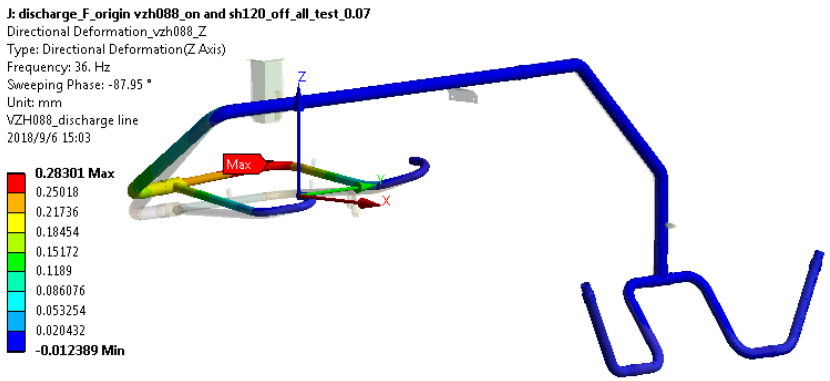
# (6)谐响应加载及计算结果

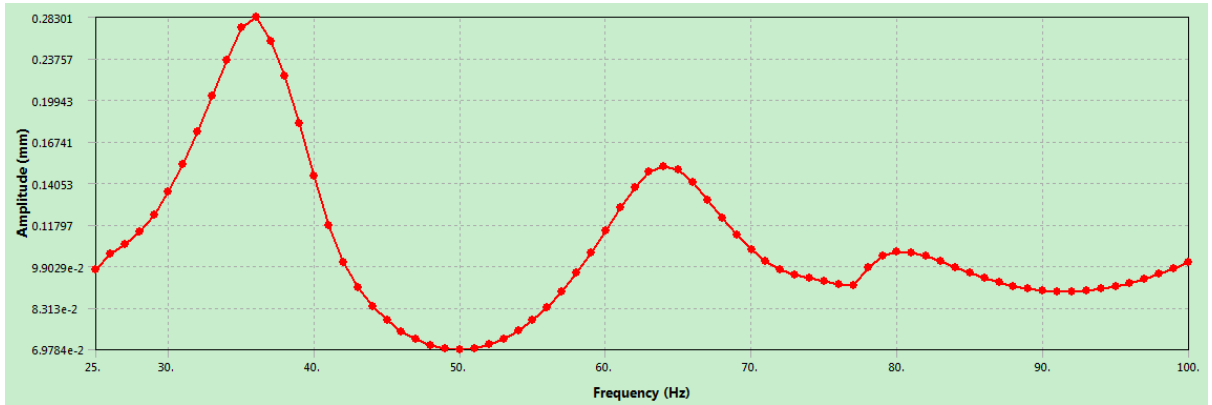
- 加载




在 运行压缩机排气口出加载位移，位移大小来自实验数据

- 结果

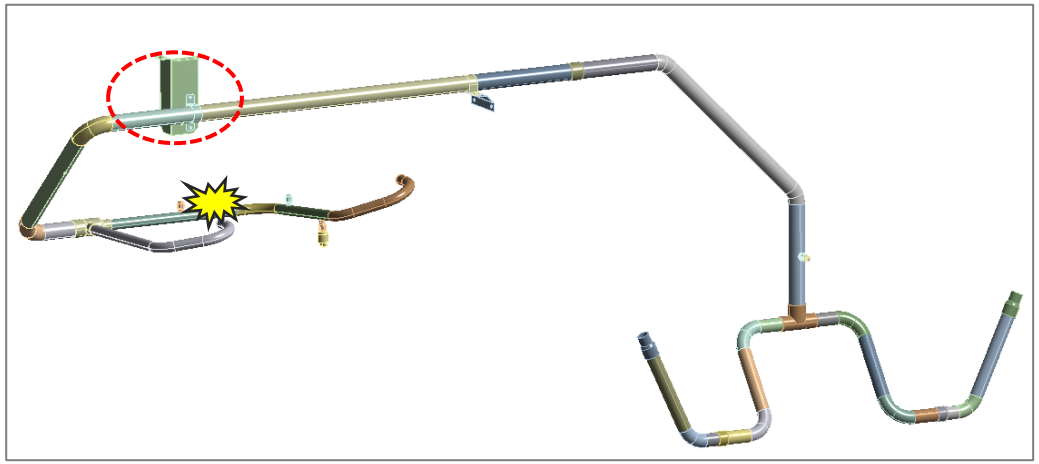


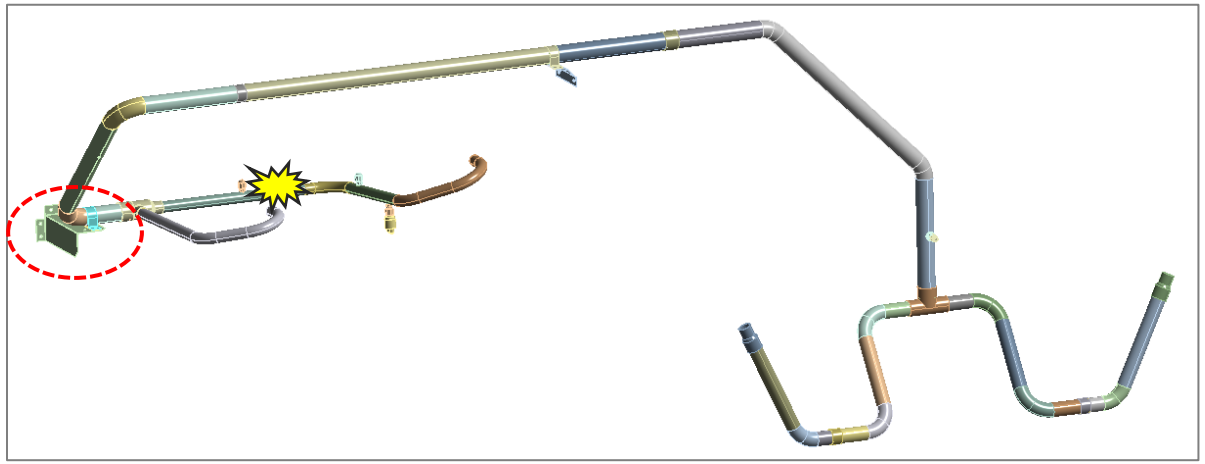

36Hz, 管路振幅283.01微米,对应峰峰值的有效值是400.24微米($\sqrt{2}$*A)

# 改善方案

## ◆ 支撑位置方案1



之前

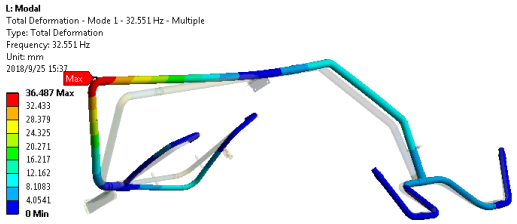


之后

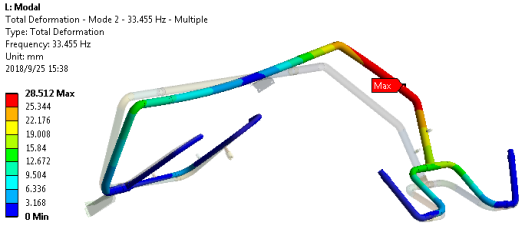
- 支撑位于长直管段
- 支撑位于短直管段和弯管交口处

# A. 模态分析

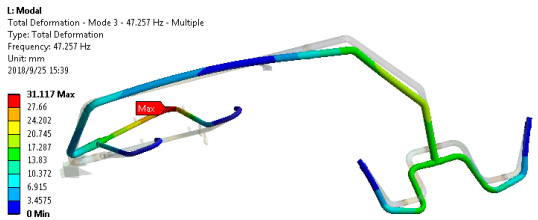
第一阶模态频率: 32.551Hz



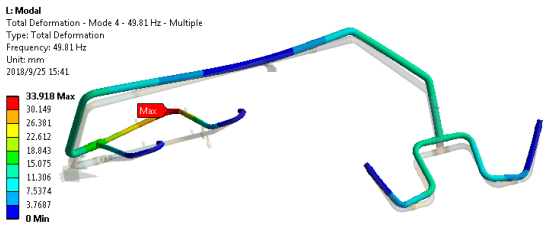

第二阶模态频率: 33.455Hz



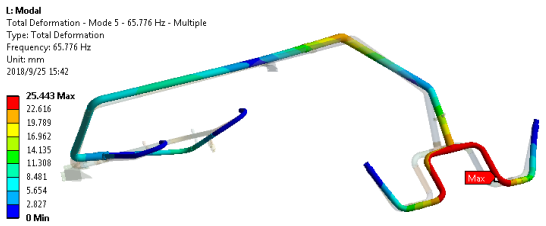

第三阶模态频率: 47.257Hz



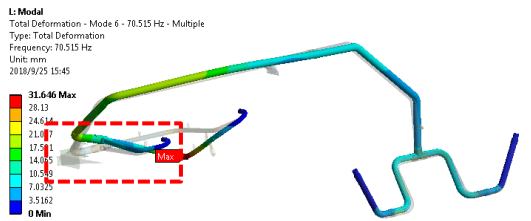

第四阶模态频率: 49.81Hz



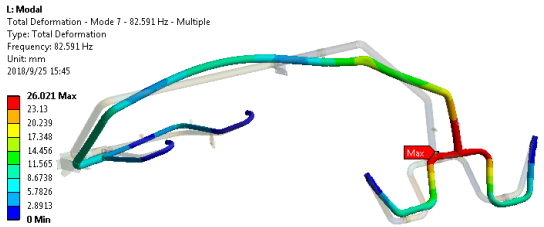

第五阶模态频率: 65.776Hz



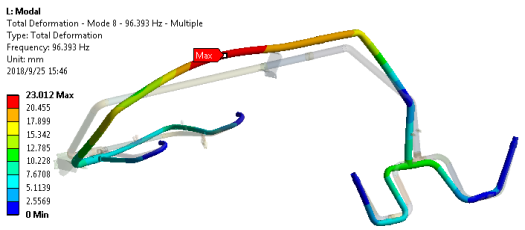

第六阶模态频率: 70.515Hz




第七阶模态频率: 82.591Hz



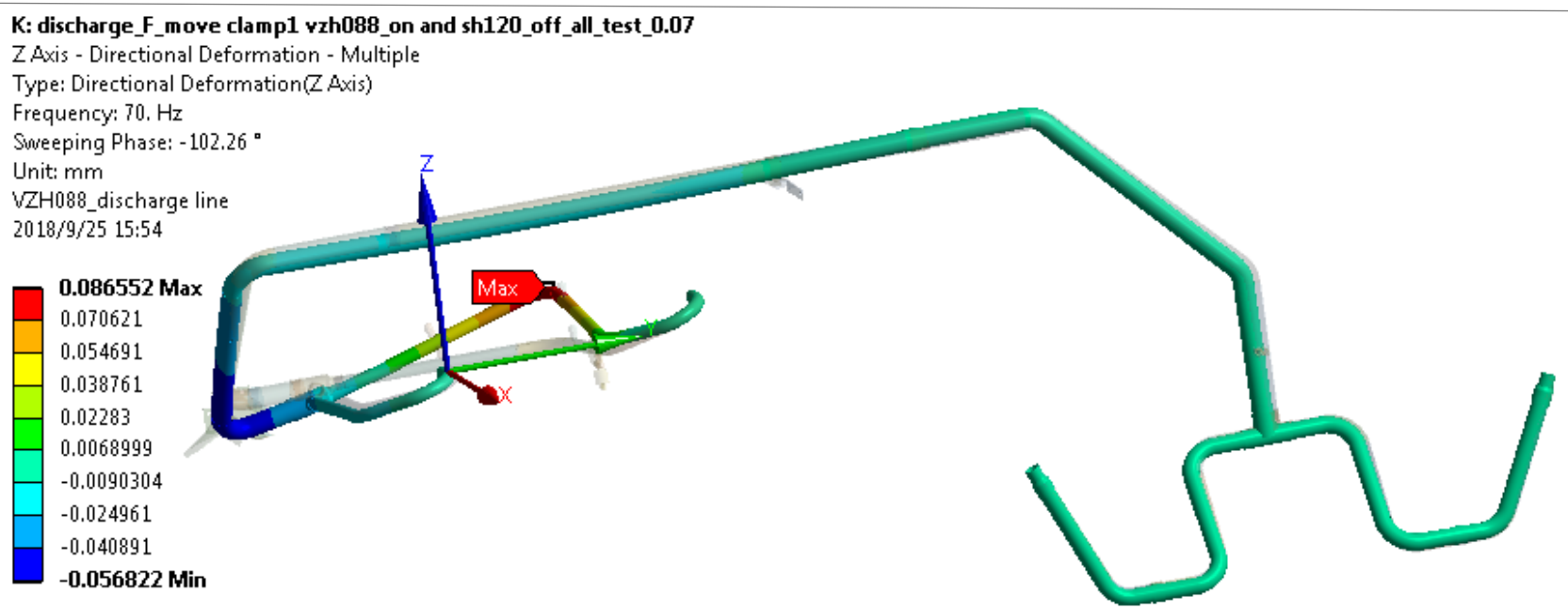

第八阶模态频率: 96.393Hz




| Mode | Frequency [Hz] |
|---|---|
| 1. | 32.551 |
| 2. | 33.455 |
| 3. | 47.257 |
| 4. | 49.81 |
| 5. | 65.776 |
| 6. | 70.515 |
| 7. | 82.591 |
| 8. | 96.393 |
| 9. | 107.4 |

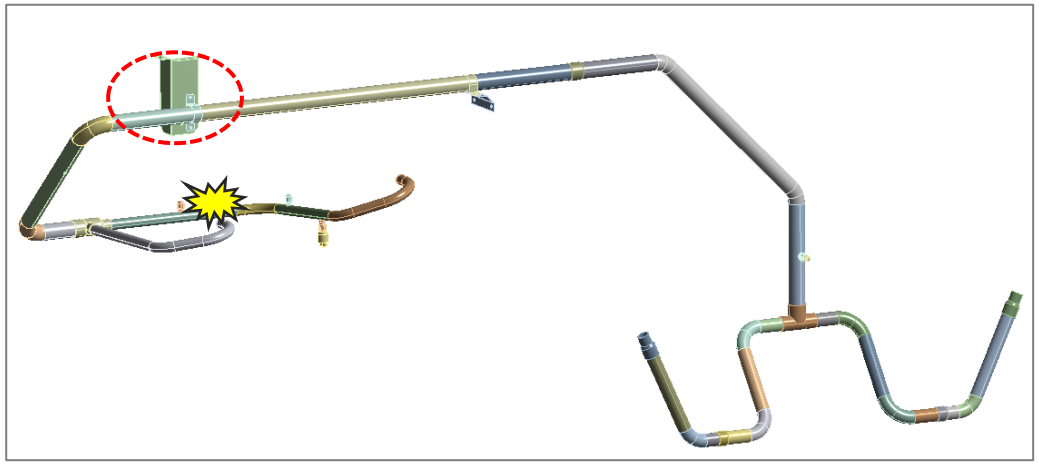
在变频压缩机运行范围25~100Hz内有8阶模态频率.

# B. 谐响应分析

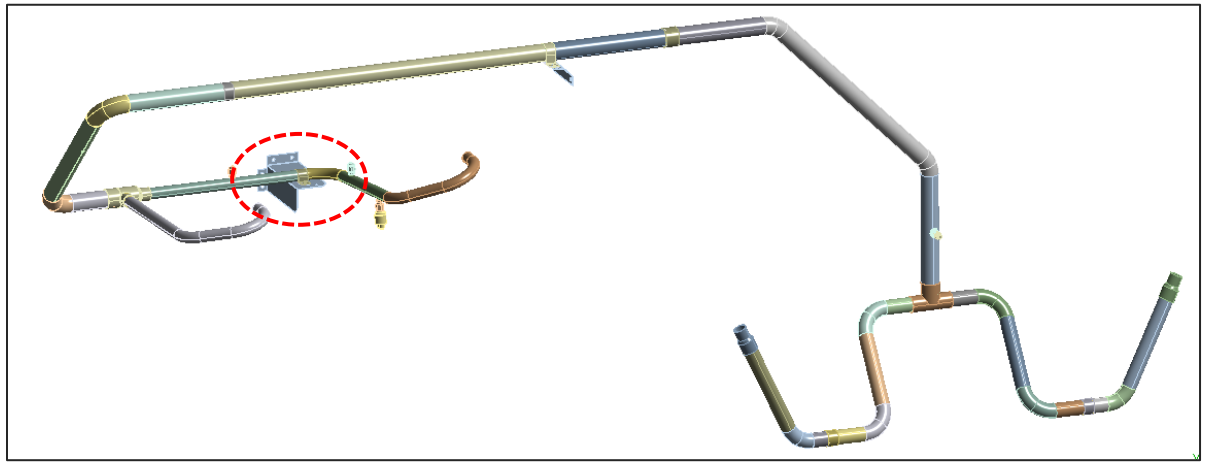



最大振幅在70Hz，振幅是86.552 微米，对应峰峰值的有效值是122.4微米($\sqrt{2}$*A)

## ◆ 支撑位置方案2



之前

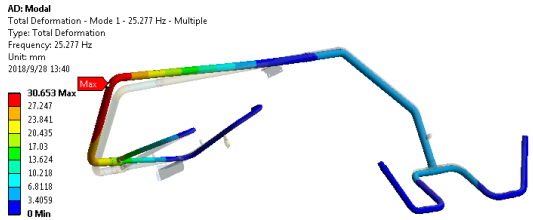


之后

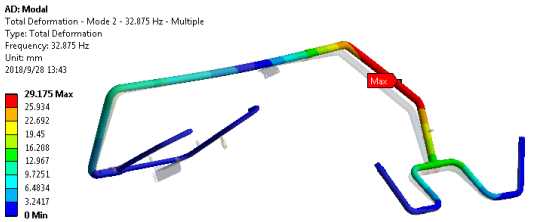
- 支撑位于长直管段
- 支撑位于振动位置最大处

# A. 模态分析

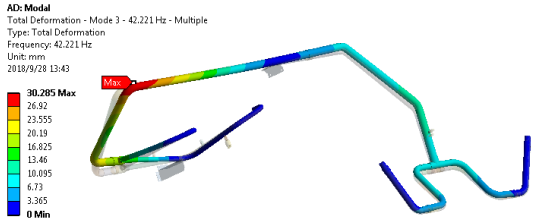
第一阶模态频率: 25.277Hz



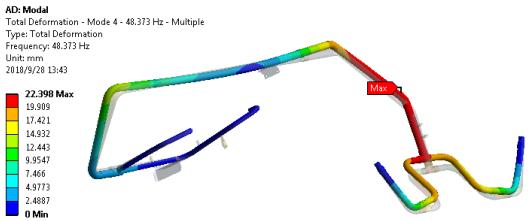

第二阶模态频率: 32.875Hz



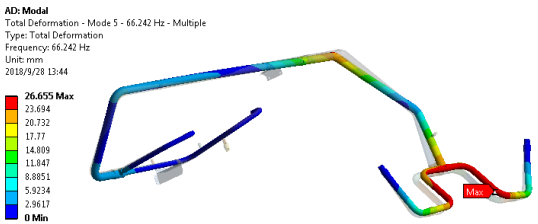

第三阶模态频率: 42.221Hz



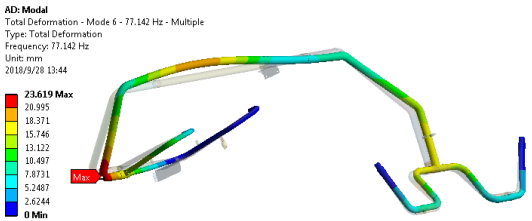

第四阶模态频率: 48.373Hz



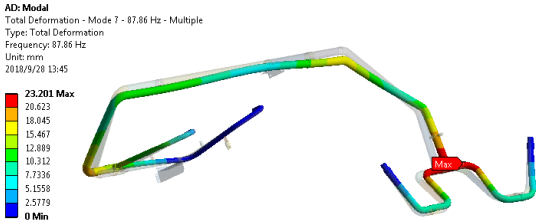

第五阶模态频率: 66.242Hz




第六阶模态频率: 77.142Hz



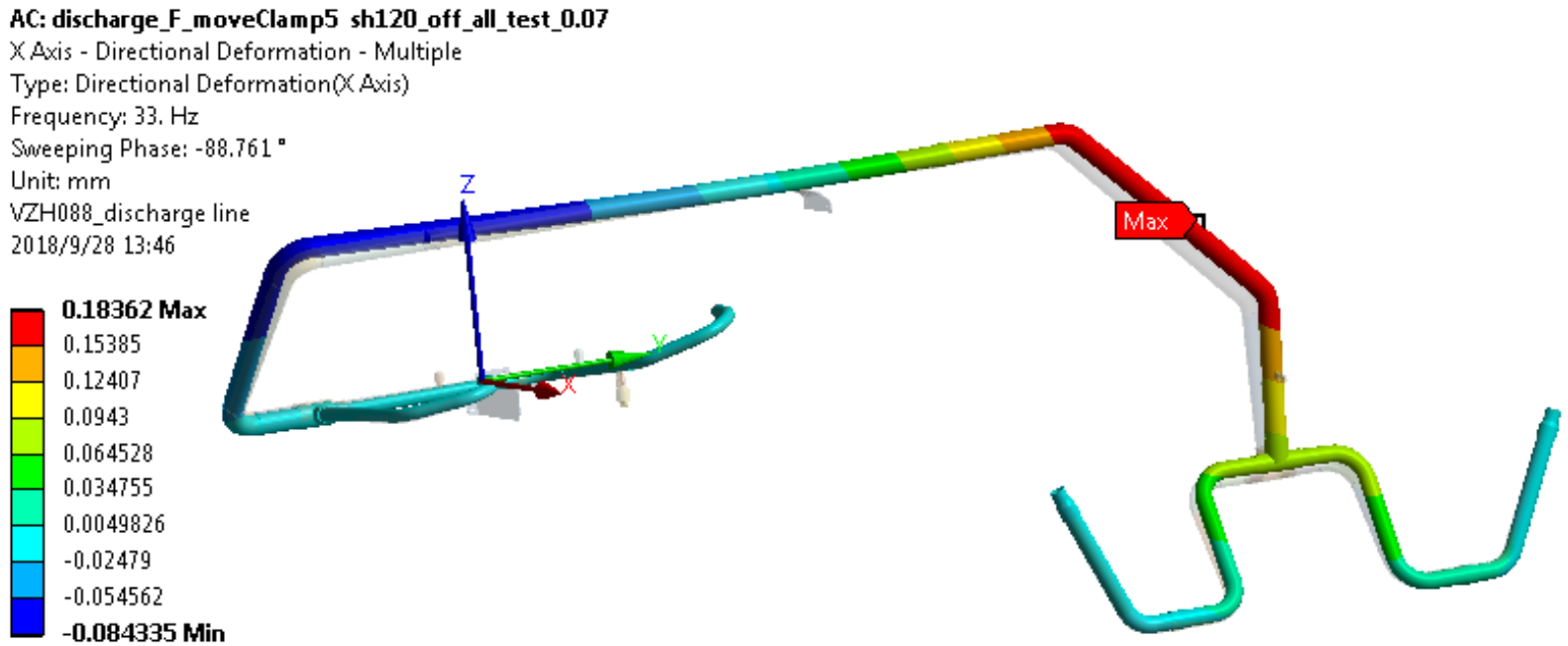

第七阶模态频率: 87.86Hz




| Mode | Frequency [Hz] |
|---|---|
| 1. | 25.277 |
| 2. | 32.875 |
| 3. | 42.221 |
| 4. | 48.373 |
| 5. | 66.242 |
| 6. | 77.142 |
| 7. | 87.86 |
| 8. | 103.62 |

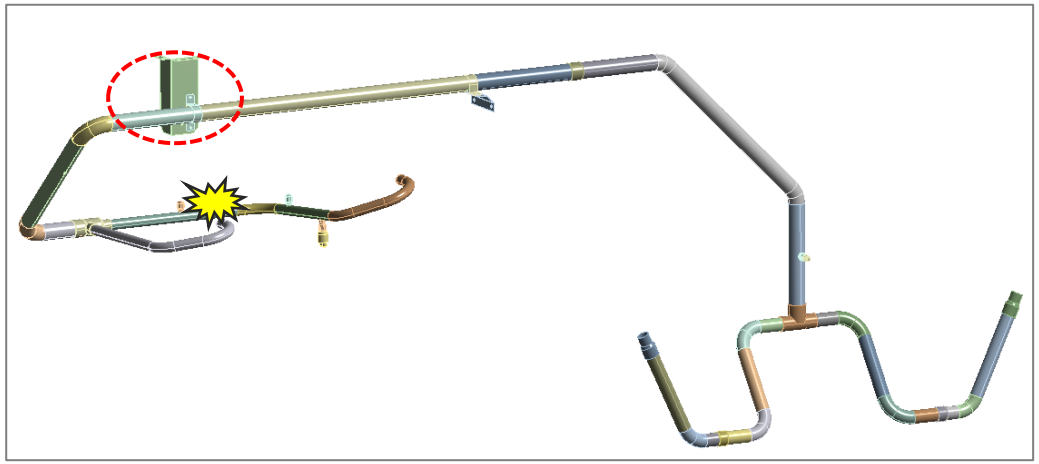
在变频压缩机运行范围25~100Hz内有7阶模态频率.

# B. 谐响应分析

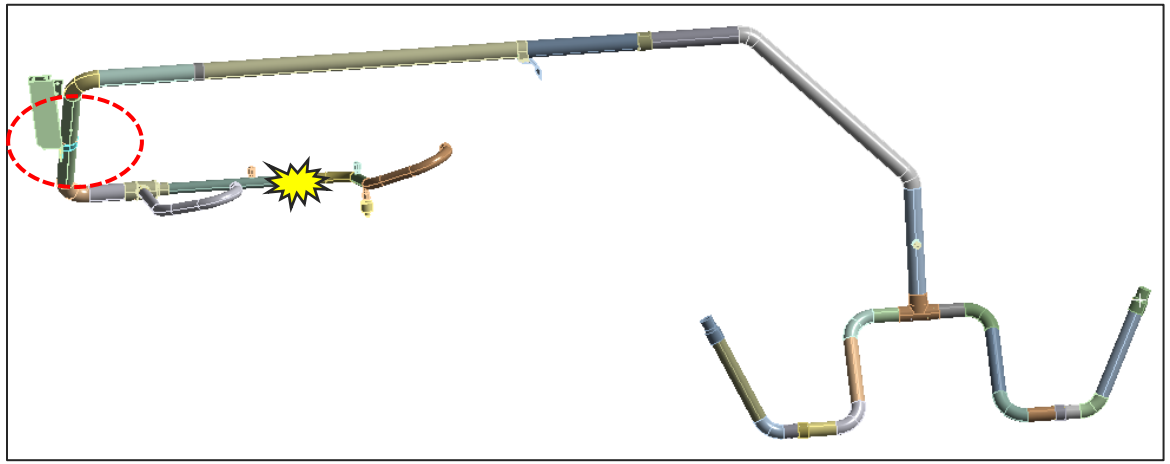



最大振幅在33Hz，振幅是183.62 微米，对应峰峰值的有效值是259.678微米($\sqrt{2}$*A)

## ◆ 支撑位置方案3



之前

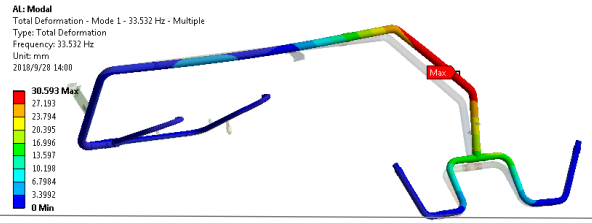


之后

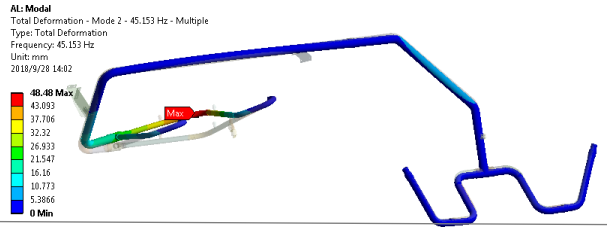
- 支撑位于长直管段
- 支撑位于垂直管

# A. 模态分析

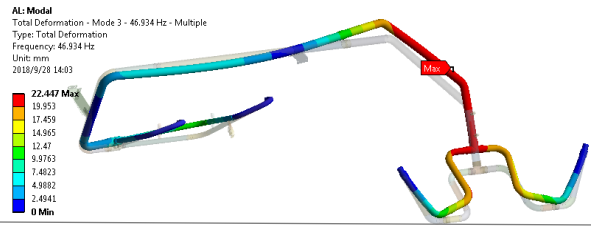
第一阶模态频率: 33.532Hz



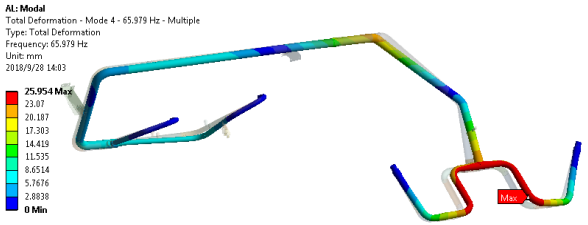

第二阶模态频率: 45.153Hz



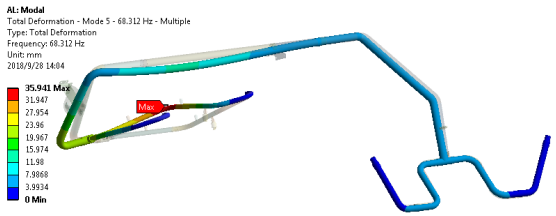

第三阶模态频率: 46.934Hz



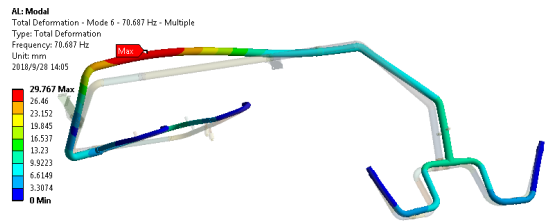

第四阶模态频率: 65.979Hz



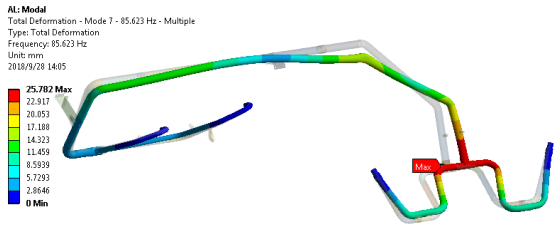

第五阶模态频率: 68.312Hz




第六阶模态频率: 70.687Hz



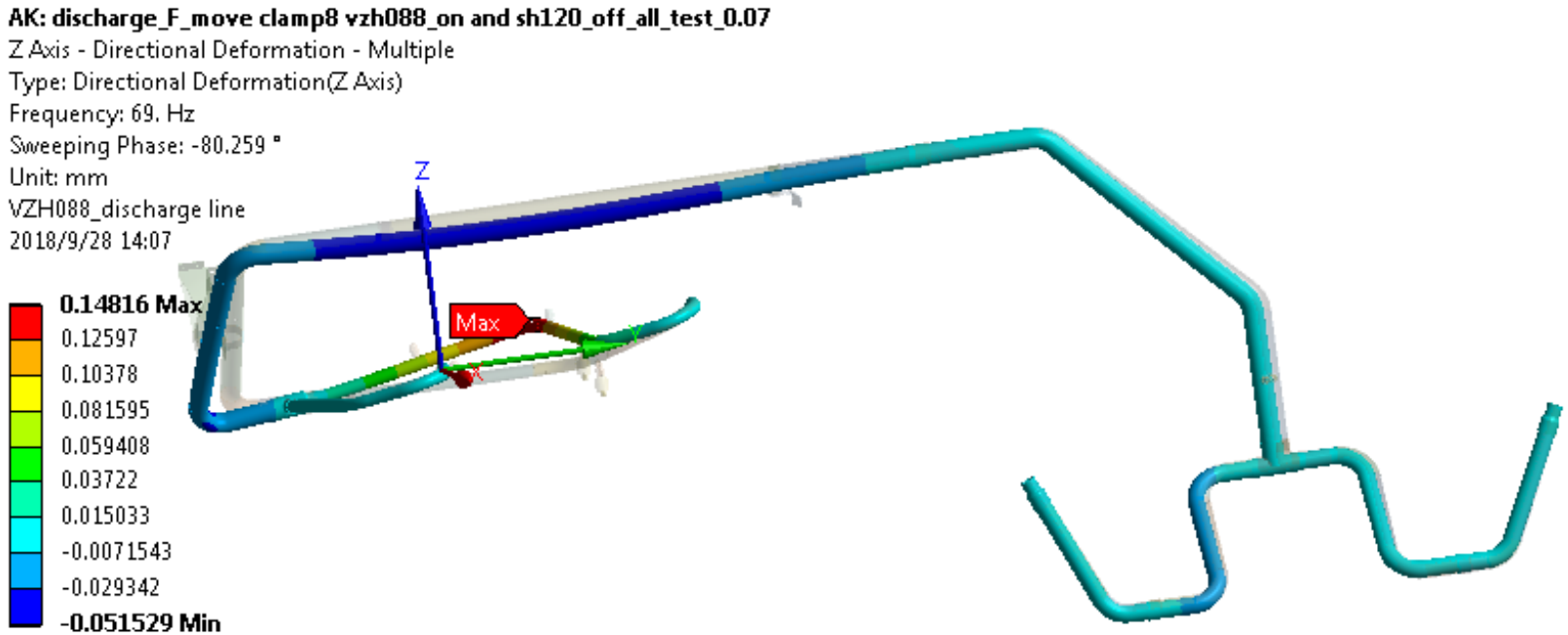

第七阶模态频率: 85.623Hz




| Mode | Frequency [Hz] |
|---|---|
| 1. | 33.532 |
| 2. | 45.153 |
| 3. | 46.934 |
| 4. | 65.979 |
| 5. | 68.312 |
| 6. | 70.687 |
| 7. | 85.623 |
| 8. | 101.27 |

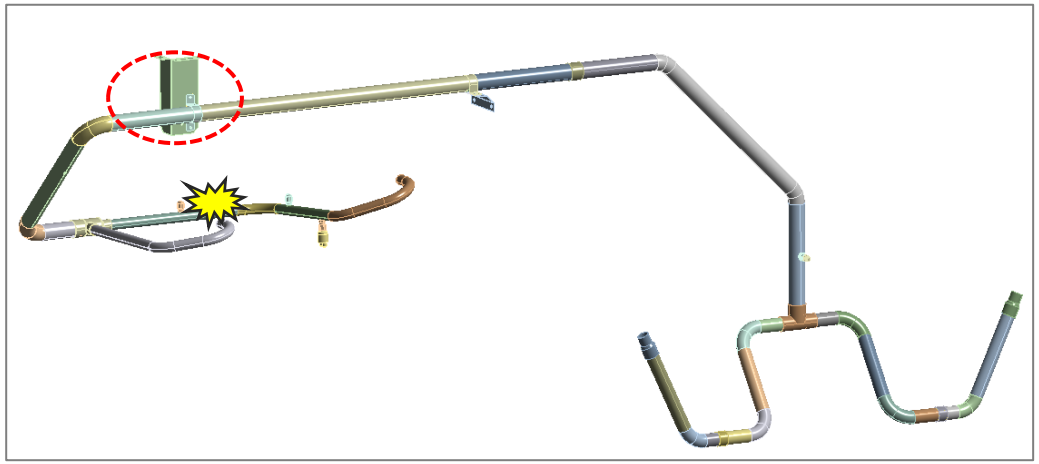
在变频压缩机运行范围25~100Hz内有7阶模态频率.

# B. 谐响应分析

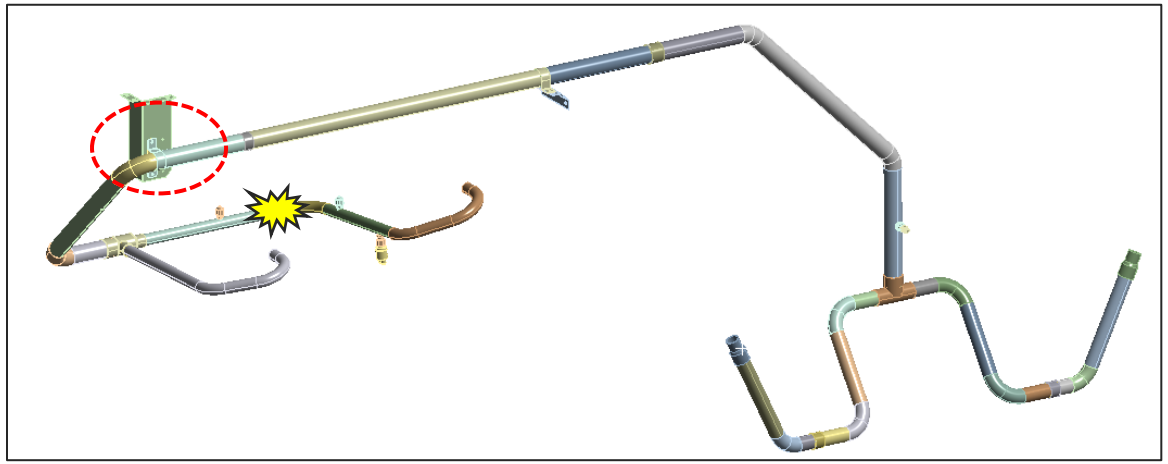



最大振幅在69Hz，振幅是148.16 微米，对应峰峰值的有效值是209.53微米($\sqrt{2}$*A)

## ◆ 支撑位置方案4



之前



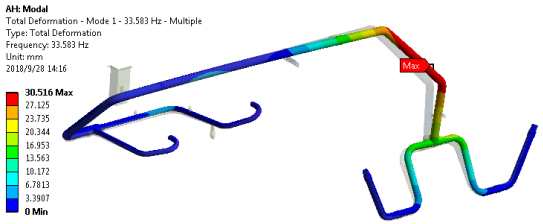
之后

- 支撑位于长直管段

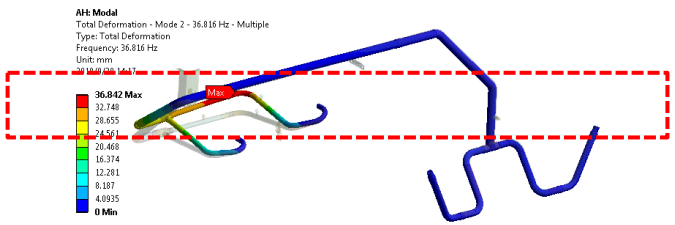
- 支撑位于长直管段左侧

# A. 模态分析

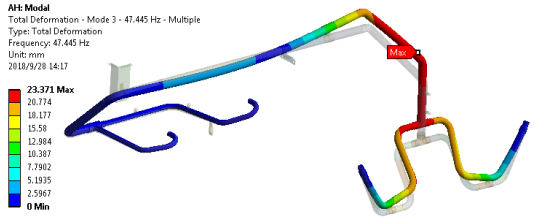
第一阶模态频率: 33.583Hz



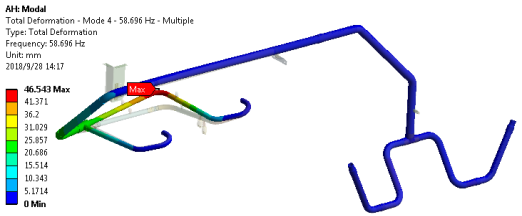

第二阶模态频率: 36.816Hz



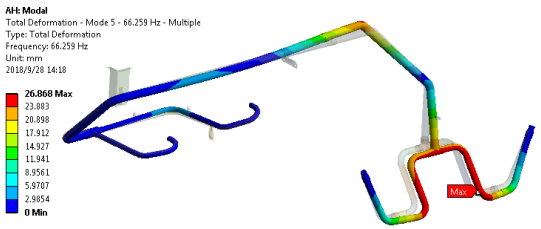

第三阶模态频率: 47.445Hz



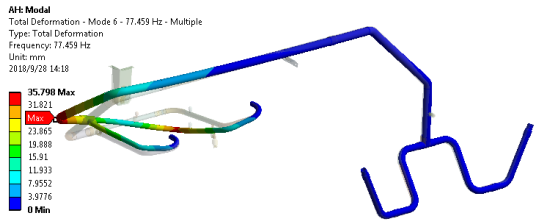

第四阶模态频率: 58.696Hz



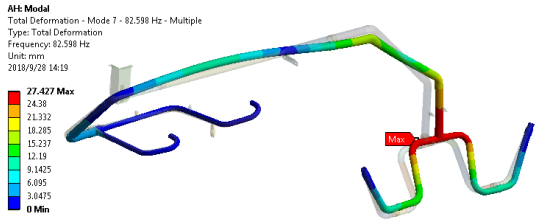

第五阶模态频率: 66.259Hz



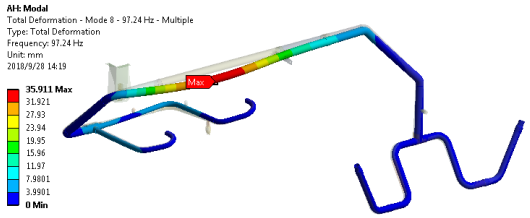

第六阶模态频率: 77.459Hz




第七阶模态频率: 82.598Hz



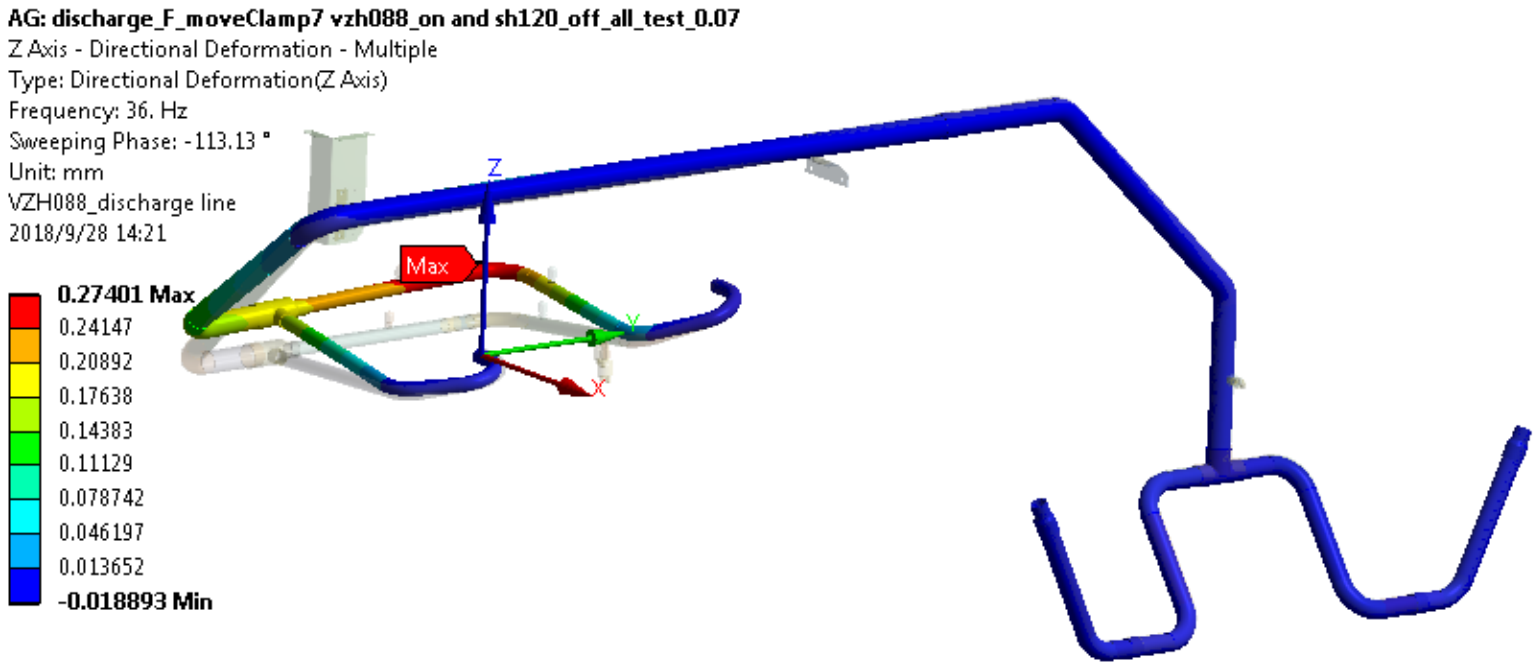

第八阶模态频率: 97.24Hz




| Mode | Frequency [Hz] |
|---|---|
| 1. | 33.583 |
| 2. | 36.816 |
| 3. | 47.445 |
| 4. | 58.696 |
| 5. | 66.259 |
| 6. | 77.459 |
| 7. | 82.598 |
| 8. | 97.24 |
| 9. | 113.67 |

在变频压缩机运行范围25~100Hz内有8阶模态频率.

# B. 谐响应分析




最大振幅在36Hz，振幅是274.01 微米，对应峰峰值的有效值是387.509微米($\sqrt{2}$*A)

# 结论

- 通过对比原始管路的模态振型和客户实际振动情况，确定造成振动位移过大的原因是由于排气管路系统在第二阶固有频率发生了共振；
- 通过四种管路支撑方案的计算，我们知道固定支撑方案1对降低管路振动效果最好，最大振幅从400微米减小到122.4微米

Ansys

# INNOVATION CONFERENCE

2021