# EFFECT OF STATOR SLOTS AND POLES ON THE DESIGN OF ROTATING MACHINE

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**Abstract**

Unsuitable combinations of stator and rotor slots with unsuitable number of poles generate high level of harmonic content and malfunctions of rotating machine when set into running operation. If this situation is not arrested, this could lead to the entire breakdown of machine. In rotating machine design, the stator slots must be able to run effectively with the suitable number of rotor slots so as to avoid cogging and winding vibrations. The manufacturer needs to know the level of harmonic contents of that machine to be wound in order to run a particular load. The rewinder should not rewind a stator with pole that will bring abnormal operation of that machine by considering the suitable stator slots and poles that will prevent the coil from undergoing heating effect. The winding may be symmetrical, unsymmetrical, balanced or unbalanced and these depend on the number of stator slots and the number of poles. This paper presents the effect of harmonic contents on the number of stator slots and poles of rotating machines.

**Keywords**: harmonics, stator slots, rotor slots, poles, winding

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## Introduction

The number of stator slots and the number of poles have effect on harmonic content of a given rotating machine. If the number of slots per phase per the greatest common factor between the number of slots and the pole pairs is an integer, it is a balance winding. An unbalanced winding does not allow the arrangement of the coils in such a way that they produce a symmetrical system of equally phase time displaced electromotive force of identical magnitude, frequency and waveform. The unbalanced winding appears when the number of pole pairs is a multiple of 3, that is, p=6, 12, 18 etc. The greatest common factor between the number of slots and the pole pairs indicates the number of winding symmetries. However, the integral multiple of the fundamental frequency is known as the harmonics. Harmonic currents generate heat in the winding, core and rotor which result in core and copper loss [1]. Harmonics reduction can be achieved by other methods such as skewing or angle stator slots to eliminates ripple harmonics [2], bevel the pole tips increases the air gap thereby increasing the reluctance of the flux path resulting in the reduction of harmonics, suitable combination of stator and rotor slots, using chorded winding with integral number of slots per pole per phase weakens the stator winding magnetomotive force harmonics thus minimizing the effect of harmonic torque and symmetrical lap winding distribution [3]. The wider the slots opening, the greater the harmonics and more stator slots give better winding distribution [4], but increase the harmonic content of the rotating machine. This is applicable where reduction of the number of slots at constant number of pole is needed to obtain reduction in harmonic content of the machine. In repair workshop, the following results of number slots and their corresponding poles of three phase squirrel cage induction motors are shown in Table 1.

Table 1.Number of poles and number of stator slots

| 2P | Number of slots |
|---|---|
| 2 | 12, 18, 24, 30, 36, 42, 48 |
| 4 | 12, 18, 24, 36, 42, 48, 60, 72 |
| 6 | 36, 54, 72, 84, 96 |
| 8 | 48, 72, 84, 96 |
| 10 | 60, 90, 120 |
| 12 | 72, 90, 108, 144 |
| 14 | 84, 126, |

| | |
|---|---|
| 16 | 96, 144 |

Two motors of 18 slots with two and four poles respectively are investigated. The coil configuration of the two poles is shown in Table 2

Table 2 Coil configuration of an induction motor with 18 slots and two poles

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | A | A | C | C | C | B | B | B | A | A | A | C | C | C | B | B | B |

The number of stator slots, Z=pqm

Where p is the number of poles, q is the number of poles per pole per phase and m is the number of phases

Number of slots per pole per phase, q=18/(2x3)=3

Figure 1 shows the winding diagram of eighteen stator slots with two poles

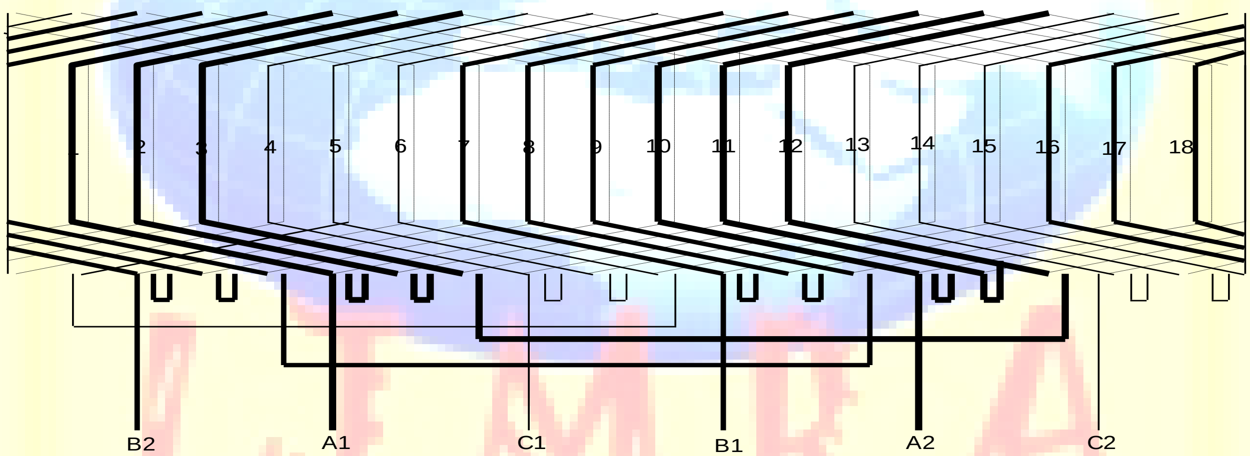


Fig. 1: Winding diagram of a motor with Z=18 and 2P=2

Table 2 shows the coil configuration of four pole induction motor with eighteen slots and the winding diagram is shown in Figure 2. The motor can work efficiently with two and four poles but cannot be used for six or more poles because of the generation of high harmonic content and multiple harmonics developed and this is shown in Figure 3

The number of slots, Z=18

The number of poles, p=4

The number of phases, m=3

The number of slots per pole per phase, q=18/(4x3)=3/2 (fractional slot winding)

Table 2. Coil configuration of an induction motor with 18 slots and four poles.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 1 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 |
| A | C | C | B | A | A | C | B | B | A | C | C | B | A | A | C | B | B |

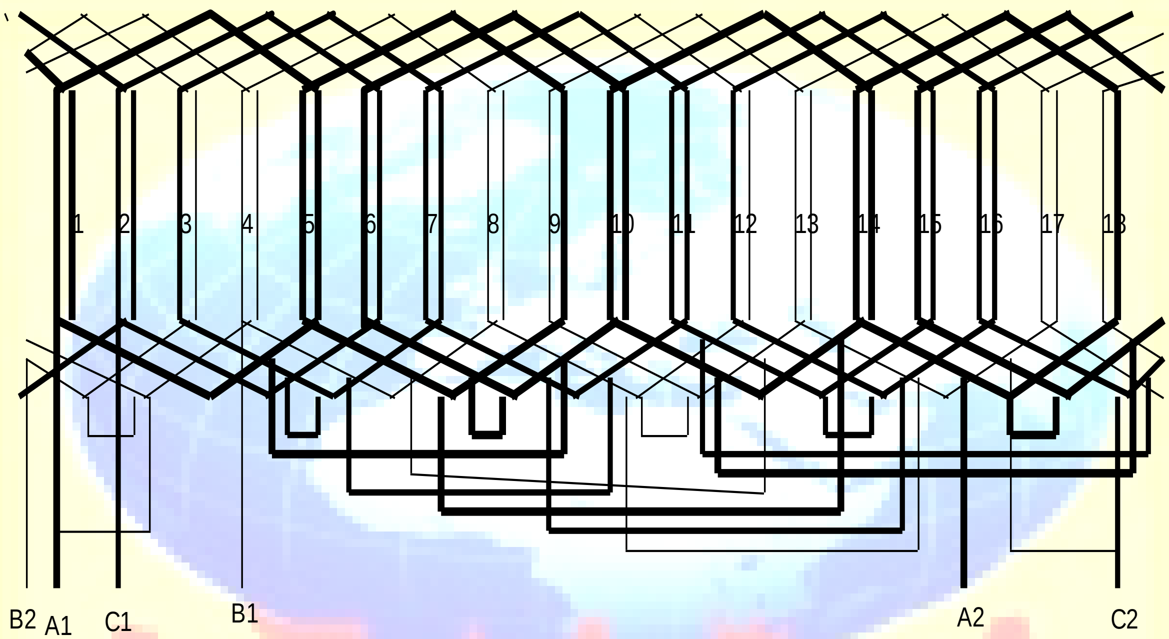


Fig. 2: Winding layout of double layer winding with Z=18 and 2P=4

The two motors are investigated through simulation using Emetor Electric Winding software and harmonic contents of each of the respective poles are shown in figure 3 and 4

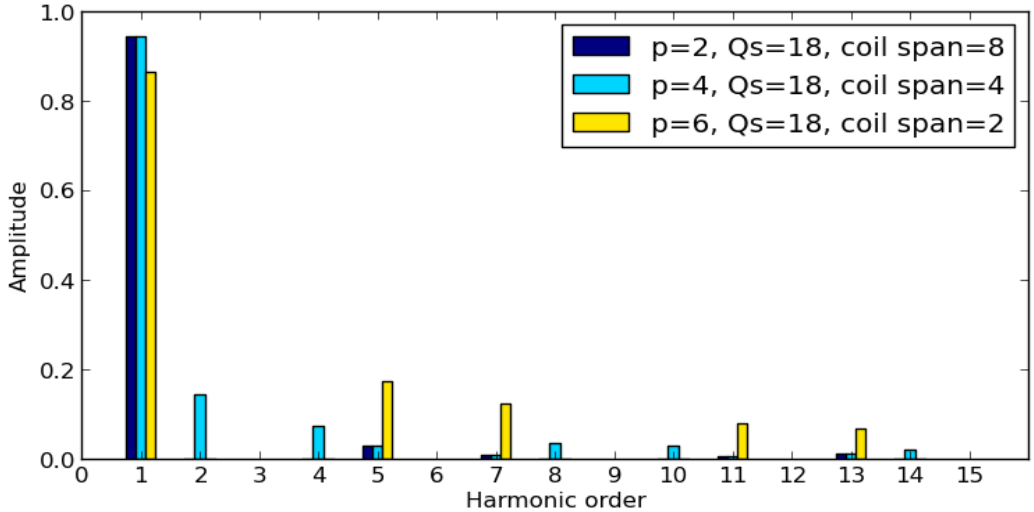


Fig. 3 Three phase mmf

In figure 3, when p=2, the winding has a symmetric and balanced, the even harmonics due to north and south pole neutralizes each other and only the 5th, 7th , 11th and 13th harmonics are present. As p=4, the winding has two symmetries but an unbalanced winding with the presence of 2nd, 4th, 5th, 8th, 10th and 14th harmonic. The winding has 3 symmetries when p=6 and the winding is balanced. In a balanced winding, the only harmonics that can be generated are not multiples of 2 or 3. It is evident in figure 4 that the stator poles with six poles have higher harmonic content of its winding factor.

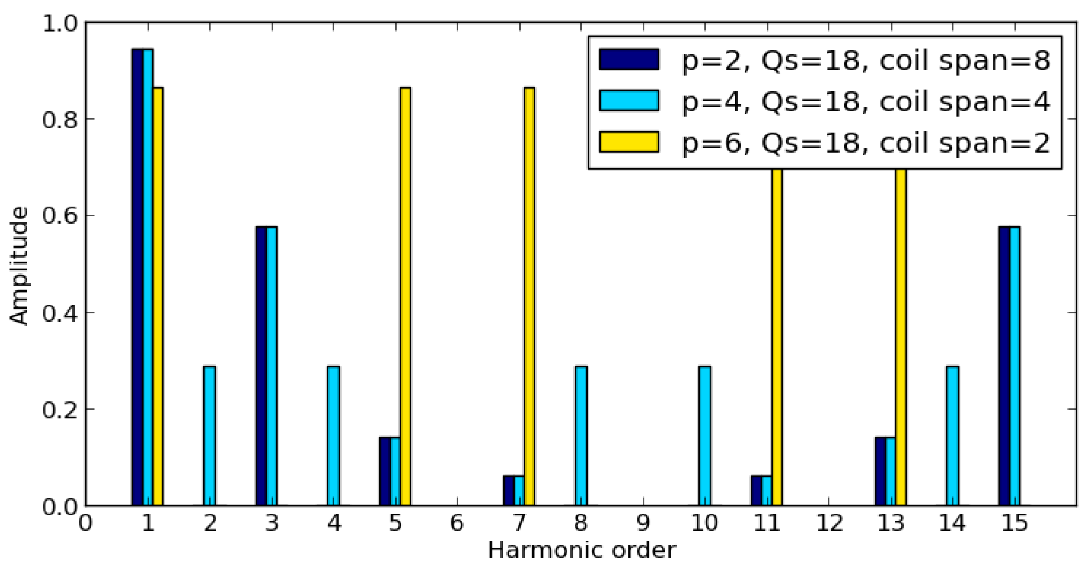


Fig. 4. Winding factor

**Result**

Figures 3 and 4 show that the incorrect choosing of poles for the number of stator slots in a rotating machine can generate higher harmonics which can lead to reduction of life span of the winding, core and laminations.

**Conclusion**

During machine design, it is good to ensure proper selection of stator slots and the number of poles for respective rotating machines in order to prevent higher harmonics that can result in the heating of coils, core and laminations which can lead to losses and reducing the efficiency of the machines

**References**

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